IN-SITU TREATMENT
of
OILED SEDIMENT SHORELINES
PROGRAMME

1996 SVALBARD SHORELINE FIELD TRIALS

prepared by

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December 31 1996

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PREFACE

The Svalbard Shoreline Field Trials and the Beach Basin Trials are two studies combined under the In-situ Treatment of Oiled Sediment Shorelines Programme. This document reports on the first phase of the Svalbard Shoreline Field Trials conducted in 1996.

The In-situ Treatment of Oiled Sediment Shorelines Programme is being financially sponsored by the following agencies.

Canadian Coast Guard

Environment Canada

Exxon Research

Imperial Oil Canada

Marine Pollution Control Unit (UK)

Minerals Management Service (USA)

Norwegian Pollution Control Authority

Texas General Land Office

Further information on the programme can be obtained from the Project Managers

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EXECUTIVE SUMMARY

The 1996 field season of the Svalbard Shoreline Field Trials was conducted between July 20 and August 20th, at experimental sites near Sveagruva, Svalbard, Norway. Baseline field work and field protocol development were successfully completed and the results will be used to design the full-scale field trials scheduled for 1997. The 1996 field activities and objectives were as follows.

- Beach surveys were conducted to document shoreline and substrate character and to determine those segments suitable for the experimental field trials.
- Oil penetration and short term retention testing were conducted using the test oil IF-30, a residual #4 fuel oil.
- Options for oil release were examined and a test discharge system constructed.
- A single plot was oiled and monitored for two weeks to document changes in oil cover, penetration, and loading and test experimental design.
- Protocols were tested for the collection of samples and extraction of oil from bulk sediment samples.

Findings and recommendations with respect to the 1996 activities are as follows.

Suitable sites for the 1997 field trials are located on Beaches 1, 2 and 4. Beach #2 would be used for a tilling, bioremediation, tilling combined with bioremediation, and a control plot. This beach has the longest stretch of suitable intertidal sediment and will therefore permit all plots to be located on similar sediments with similar exposure. Beach #1 is recommended for surf washing (sediment relocation) in a low energy setting. As one of the aims of this research programme is to study the acceleration of OFI, it is of interest to test surf washing, a technique usually used on high energy beaches, as a method of enhancing OFI as opposed to mechanical abrasion. It would also be desirable to carry out surf washing on Beach #4, a high energy beach. Previous cleanup operations have demonstrated that surf washing can be an effective technique, but quantitative data has not been collected during these spill events. A surf washing study on Beach #4 would provide relevant data to support this technique.

It was the concluded that the IF-30 oil can be used in the 1997 field trials without modification. This same oil will be used in the beach basin experiments in Trondheim and Texas. An estimated oil loading of 5L/m^2 will be used, however the final loading will be based on the results from the basin experiments.

The discharge system will be similar to that used in the 1996 field trials but with a higher discharge capacity. Oil will be pumped through a perforated pipe which will be long enough to span the entire cross shore width of the plot.

The top of each plot will be located at or just below the spring high water mark and will include all of the UITZ. Depending on the treatment, plot sizes of 30 - 40 m alongshore length and 3 - 4 m cross shore width will be used. Timing for oiling and treating the plots will be coordinated with specific phases of the monthly cycle of spring and neap tides. The strategy will be to allow the maximum time for the oil to penetrate and adhere into the sediment before natural tidal flushing and application of treatment techniques. All test plots will be oiled during the neap tide phase from July 28 to Jul 31, 1997. The treatments will be carried out during the peak of the spring tide phase, approximately 8 to 10 days after oiling, An additional option is also proposed for treatment after 72 hours.

A systematic sample scheme will be used on the plots (as per 1996) taking 1 sample per bloc per sample period. A sample size of about 2 kg - 3kg or about 1.5 L will be used. This is of sufficient size to overcome sediment heterogeneity. In most cases, intertidal surface and subsurface will not be separated or sub-sampled. A single sample will be composed of a vertical composite of sediment from the surface to a fixed depth. Based on analysis of 1996 data, an estimated 10 samples per 4 x 20 m plot is deemed adequate. In the case of surf washing where the sediments on the oiled plot have been moved, then the sampling grid for the relocated sediment berms will be contoured to the shape and redistribution of the berms.

The basic bulk sediment extraction protocol used in 1996 will be used in 1997 with modifications in equipment to improve efficiency. These will be verified in the beach basin trials in Texas and Trondheim. Total oil will be determined by gravimetric total solvent extractable material (TSEM). Samples will be archived for potential future GC-TPH or GCMS.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the participation or support from the following individuals and agencies for the 1996 Field Trials;

- Ole Hansen and the Office of the Governor of Spitsbergen, for provision of a permit allowing the release of the test oil,
- Store Norske Spitsbergen Kullkompaniet, for logistical support and for allowing the experiments on their property,
- Wayne Halley, Canadian Coast Guard, for the loan of a skimmer,
- Bror Johansen, SINTEF, for field technical services in Sveagruva as well as preparing and shipping equipment to Svalbard,
- Dr. Zhendi Wang and his staff in Environment Canada who conducted the chemical analysis of sediment and oil samples,
- Patrick Lambert, Environment Canada, for expediting and providing equipment and handling incoming samples,
- Blair Humphrey, EnviroEd, for advice regarding bulk sediment sampling.

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GLOSSARY

Shoreline Materials/Substrate:

R	Bedrock outcrops	
B	Boulder	(> 256 mm dia.)
C	Cobble	(64 - 256 mm dia.)
P	Pebble	(4 - 64 mm dia.)
G	Granule	(2 - 4 mm dia.)
S	Sand	(0.06 - 2 mm dia.)
VCS	Very Coarse Sand	(1.0 - 2.0 mm dia.)
M	Mud/Silt/Clay	(< 0.06 mm dia.)

Intertidal Zone:

SUTZ Supratidal Zone
The area above the mean high tide that occasionally experiences wave activity. Also known as the splash zone.

UITZ Upper Intertidal Zone
The upper approximate one third of the intertidal zone.

MITZ Mid Intertidal Zone
The middle approximate one third of the intertidal zone.

LITZ Lower Intertidal Zone
The lower approximate one third of the intertidal zone.

Other

Groyne
A barrier built on a coast (at right angles to the shoreline) to trap sand moving alongshore.

OFI
Oil and fines interaction. An event or process by which fine particles interact with oil in an aqueous environment and change it's behavioural characteristics. It may create a stable, buoyant water-sediment-oil emulsion. OFI is thought to be an important component of the natural weathering of oil by enhancing and accelerating physical and biochemical degradation processes.

TPH
The sum of all GC-resolved and unresolved hydrocarbons. The resolvable hydrocarbons appear as peaks and the unresolvable hydrocarbons appear as the area between the lower baseline and the curve defining the base of the resolvable peaks.

TSEM
Total solvent extractable materials.

1.0 INTRODUCTION

1.1 BACKGROUND

The Svalbard Shoreline Field Trials are one in a framework of linked studies being carried out by various agencies as part of a long-term strategy to better understand the behaviour of oil on shorelines and to apply appropriate response options. The Svalbard Shoreline Field Trials, in combination with the concurrent Beach Basin Trials, will investigate both the effectiveness of mainstream in-situ shoreline cleanup techniques and the natural processes for oil removal from shorelines. These field trials and basin trials are combined under the 'In-situ Treatment of Oiled Sediment Shorelines (ITOSS) Programme'.

In-situ shoreline techniques may be applied anywhere in the world and on various types of beaches and spills. Such techniques generally require fewer resources, less logistic support, and generate little or no waste materials when compared to physical removal techniques. There is no recovery of oil, rather, this suite of techniques promotes weathering and degradation processes, and thereby accelerates the removal of stranded oil. In some cases in-situ techniques can be more effective, economical, or environmentally acceptable than conventional removal techniques. In-situ techniques are particularly attractive for remote or inaccessible areas such as are common on the coasts of northern Canada, Russia, Scandinavia and Alaska. The implementation of shoreline cleanup following a spill in a remote area is limited by the constraints of available equipment and personnel, and the desire to minimize the generation of waste materials that require transport and disposal. In such cases, the preferred option is to treat the oil in situ so that environmental recovery is accelerated without the requirements for a labour-intensive effort.

The Svalbard Shoreline Field Trials are a field-scale experimental oil spill study. The emphasis is on the techniques of

- surf washing,
- tilling, and of
- tilling combined with bioremediation.

These techniques have been used on many occasions to date, however only qualitative data are available regarding relative efficiencies and the relationship between effort and success. Surf washing to accelerate natural weathering on lower wave-energy coasts through fine-particle interaction, as opposed to surf washing to induce mechanical abrasion on higher-energy coasts, is now becoming better understood as laboratory work on OFI progresses. However, to date only post-spill studies have been conducted and the time is considered appropriate to evaluate the technique by basin-scale and field-scale trials.

1.2 PROGRAMME OBJECTIVES AND PROJECT GOAL

The primary objectives of the 'In-situ Treatment of Oiled Sediment Shorelines Programme' are to:

- quantify the effectiveness of selected in-situ shoreline treatment options applicable to remove oil on remote or poor-access, mixed-sediment beaches, and
- investigate natural processes, in particular fine-particle interaction, by which oil on shoreline sediments is removed.

The goals of the project are to deliver both operational and scientific information which will assist decision makers in selecting the most appropriate technique to suit the conditions, and also to increase knowledge of the natural removal processes at work.

It should be noted that although the field trials themselves are being conducted in a high latitude location, the results have a widespread application to other coarse sediment beaches in any latitude. The extrapolation is expanded even further when supplemented with the basin trials data.

1.3 PROGRAMME OUTLINE

The In-situ Treatment of Oiled Sediment Shorelines Programme is broken down into four distinct phases, as follows:

Phase I:	Svalbard Field Trials - Part 1: Protocol development
Phase II:	Beach Basin Trials
Phase III:	Svalbard Field Trials - Part 2: Full-scale studies
Phase IV:	Svalbard Field Trials - Part 3: Follow-up studies

The experimental strategy for the programme is linked to the different project phases and basically includes:

1. Planning, organization, and experimental design.
2. Background studies, site characterization and initial control plot - summer 1996.
3. Mesoscale beach basin trials - winter 1997.
4. Field trials - summer of 1997.
5. Long term post-trial monitoring of field trial sites - 1998.
6. Optional follow-on studies - 1998.

1.4 EXPERIMENTAL DESIGN OF THE 1997 SVALBARD FIELD TRIALS

Basic elements of the 1997 Svalbard Shoreline Field Trials are likely to include:
- the use of five treatment options
  (surf washing, tilling, bioremediation, tilling plus bioremediation, natural recovery),
- one oil type (IF-30), and
- realistic sized plots, each 30-40 m in alongshore length.

The oil will be applied in a controlled and uniform manner in the upper intertidal zone. It will be applied directly to the sediment surface (not the water) which will maximize control over both the oil and the uniformity of oiling to the intertidal area. The oil will be applied on a low or falling tide, to simulate 'natural' stranding. Treatments will be applied after the oil on the beach has been stabilized by tidal washing.

A range of measurements, observations and sample collections will be carried out within and outside each of the plots, before and following the application of oil and/or treatment. These activities will include:
- observations on the physical character of the shoreline
- measurement of oil distribution
- sample collection and determination of the quantity of oil within each oiled plot
- determination of the quantity of oil outside the plots: (lower intertidal sediments; nearshore sediments and water; between plot buffer zone)
- observations and sample collection of fine particle interaction
- biodegradation-related analysis (oil composition, microbial analysis)

2.0 OBJECTIVES OF THE 1996 FIELD ACTIVITIES

The goals of the 1996 Svalbard Shoreline Field Trials were to obtain background information about the test sites and the characteristics of the test oil and sediments, and to test the various protocols and procedures to be used in the 1997 full-scale experiments. Specific objectives of Phase I were to:

- Survey candidate beaches for final selection of test plots and treatment.
- Conduct oil penetration and short-term retention testing using the test oil IF-30, in order to determine the need for blending/weathering and to optimize oil loading.
- Construct and test an oil discharge system.
- Oil a single control plot, sample and monitor as per technical proposal of April 22, 1996 to optimize observational, measurement and sampling procedures.
- Conduct and verify bulk sediment hydrocarbon extraction and analytical protocols.

3.0 MATERIALS AND METHODS

3.1 TEST LOCATION AND SITES

The field experiments were performed near the mining town of Sveagruva on Spitsbergen, the largest island in Svalbard (Figure 1). Sveagruva is located on the Van Mijenfjord, approximately 40 km from the open ocean and at approximately 76°56' North and 16°45' East.

Within this fjord, a total of five beaches were surveyed and assessed as potential sites for the 1997 experiments. These beaches (numbered 1 to 5) are indicated on Figure 1. All beaches are located approximately within 5-6 km of Sveagruva, except for Beach #5 which is approximately 10 km away.

The permit for the 1996 experiment allowed the controlled release of oil at Beaches #1 and #2. Each of these sites was surveyed and a plot for oiling was selected at the extreme south end of Beach #2. A primary factor in the selection was to ensure that this test oiling would not detract from potential beach test sites that might be suitable for 1997 trials.

At Sveagruva, ambient air temperatures in summer (June to September) average 0 to 6°C. Water temperatures range from -1 to 4°C in the summer. The salinity in the fjord is approximately 35 ppt and precipitation averages between 11 and 20 mm during this period. The ice typically leaves the fjord sometime between early to mid-July, with the shorelines becoming ice-free by late July. During the summer of 1996, the shorelines were already ice-free by mid-July. The coastal processes remain active until the beaches begin to freeze over in late November or early December. Winds during the open-water season are generally light as the region is dominated by the Polar High. Summer winds are generally light during the period June through September. The period of strongest winds occurs from November through March, coincidental with the presence of sea ice that prevents wave generation and shorefast ice that encases the beaches. Strong katabatic winds can occur near the glaciers, particularly in late autumn and early winter.

The tides are mixed semi-diurnal (two high and two low each day of unequal height) and the tidal range varies between 1.2 m and 1.8 m, depending on the spring or neap phases. Tidal ranges for the 1996 experimental period are given in Table 1.

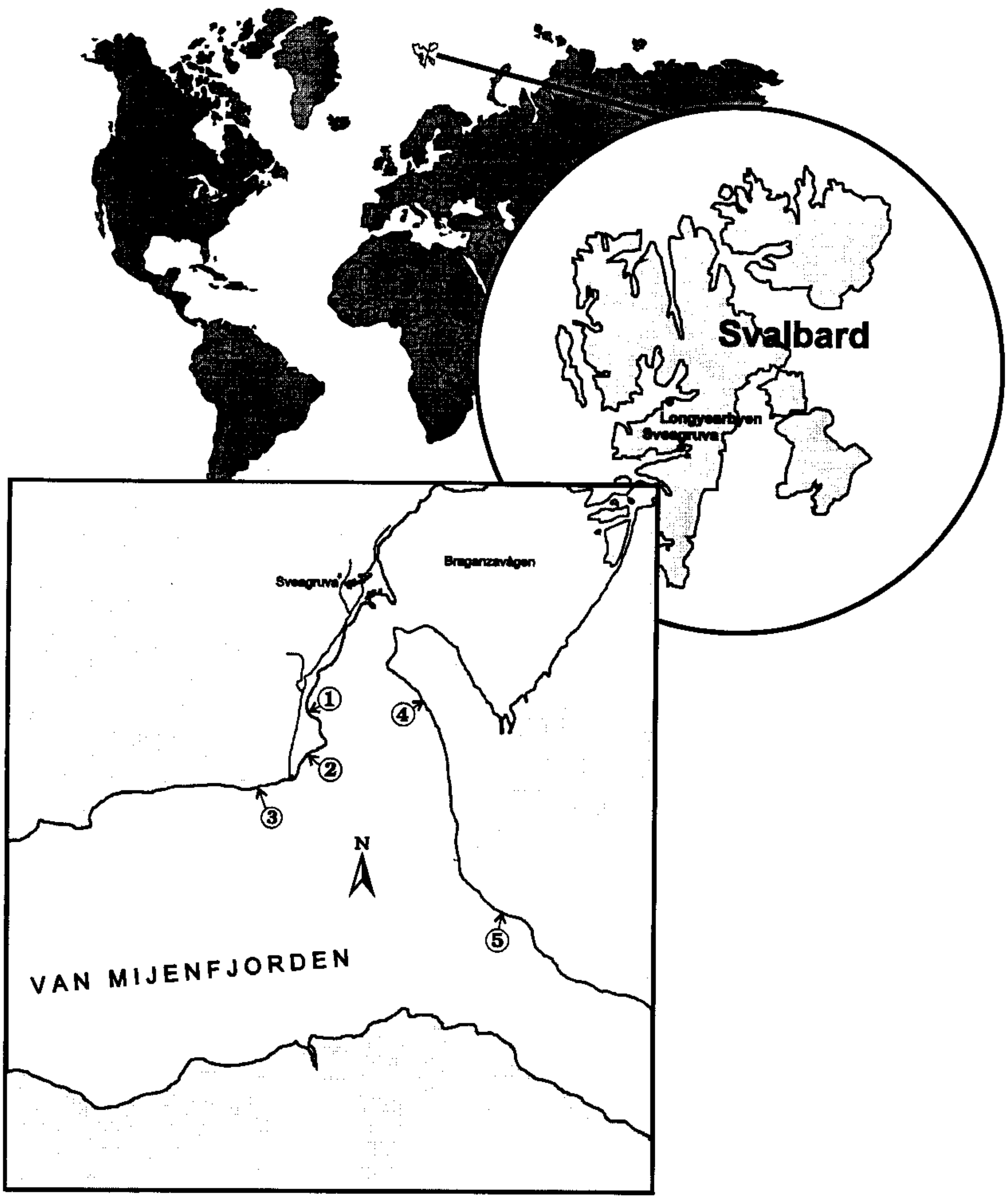
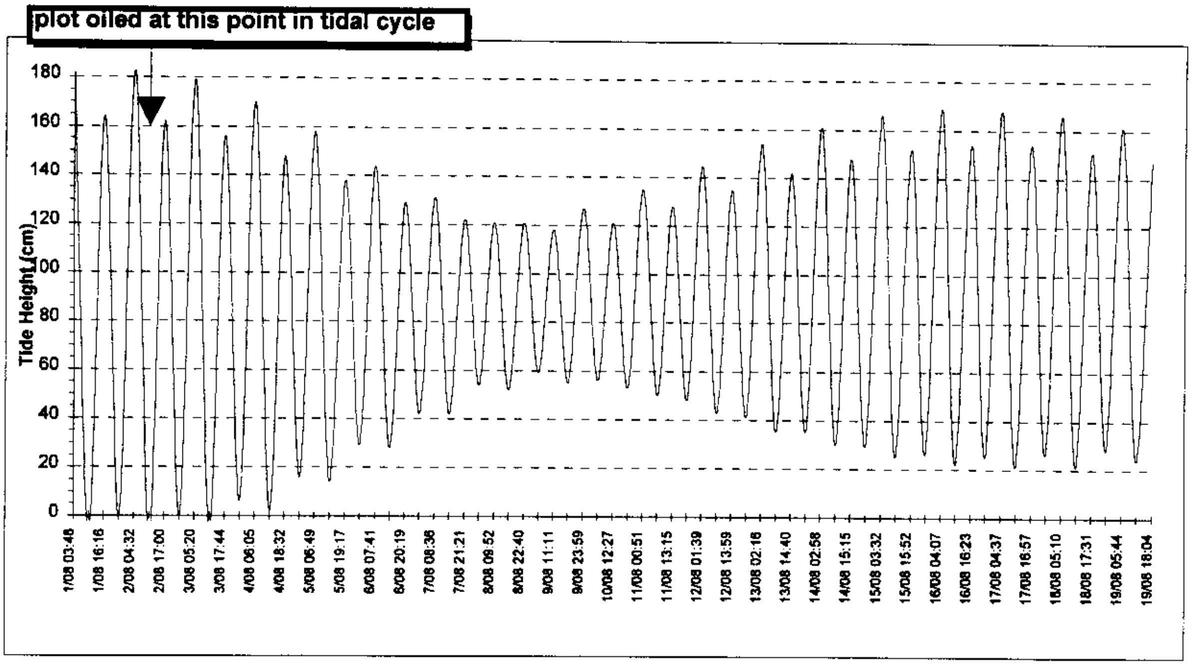


Figure 1. Location of Svalbard and Candidate Beaches

Table 1. Tide Table for Sveagruva - August 1996

Date/Time/Height		Date/Time/Height		Date/Time/Height		Date/Time/Height		Date/Time/Height	
1/08 03:48	***182***	7/08 02:21	***42***	13/08 02:16	***154***	19/08 05:44	***161***	25/08 05:25	***51***
1/08 10:07	***-7***	7/08 08:36	***131***	13/08 08:35	***35***	19/08 11:56	***24***	25/08 11:41	***125***
1/08 16:16	***164***	7/08 14:55	***42***	13/08 14:40	***142***	19/08 18:04	***147***	25/08 17:49	***47***
1/08 22:17	***-1***	7/08 21:21	***122***	13/08 20:33	***35***	20/08 00:09	***33***	26/08 00:14	***138***
2/08 04:32	***183***	8/08 03:33	***54***	14/08 02:58	***161***	20/08 06:14	***155***	26/08 06:43	***35***
2/08 10:52	***-9***	8/08 09:52	***121***	14/08 09:14	***30***	20/08 12:33	***28***	26/08 12:51	***133***
2/08 17:00	***162***	8/08 16:07	***52***	14/08 15:15	***148***	20/08 18:42	***142***	26/08 18:56	***30***
2/08 23:05	***0***	8/08 22:40	***121***	14/08 21:16	***29***	21/08 00:46	***39***	27/08 01:15	***151***
3/08 05:20	***179***	9/08 05:06	***59***	15/08 03:32	***166***	21/08 07:02	***147***	27/08 07:35	***19***
3/08 23:32	***-6***	9/08 11:11	***118***	15/08 09:44	***25***	21/08 13:10	***34***	27/08 13:43	***144***
3/08 17:44	***156***	9/08 17:30	***55***	15/08 15:52	***152***	21/08 19:30	***136***	27/08 19:44	***17***
3/08 23:45	***6***	9/08 23:59	***127***	15/08 21:51	***26***	22/08 03:34	***46***	28/08 02:03	***163***
4/08 06:05	***170***	10/08 06:22	***56***	16/08 04:07	***169***	22/08 07:43	***137***	28/08 08:19	***4***
4/08 12:20	***2***	10/08 12:27	***121***	16/08 10:19	***22***	22/08 14:02	***41***	28/08 14:31	***153***
4/08 18:32	***148***	10/08 18:32	***53***	16/08 16:23	***154***	22/08 20:21	***129***	28/08 20:33	***5***
5/08 00:34	***16***	11/08 00:51	***135***	16/08 22:25	***25***	23/08 02:26	***53***	29/08 02:48	***173***
5/08 06:49	***158***	11/08 07:20	***50***	17/08 04:37	***168***	23/08 08:45	***128***	29/08 09:04	***-6***
5/08 13:09	***14***	11/08 13:15	***128***	17/08 10:49	***21***	23/08 15:05	***47***	29/08 15:16	***161***
5/08 19:17	***138***	11/08 19:16	***48***	17/08 16:57	***154***	23/08 21:30	***125***	29/08 21:17	***-2***
6/08 01:25	***29***	12/08 01:39	***145***	17/08 22:58	***26***	24/08 03:49	***57***	30/08 03:29	***179***
6/08 07:41	***144***	12/08 07:58	***43***	18/08 05:10	***166***	24/08 10:08	***122***	30/08 09:44	***-13***
6/08 14:00	***28***	12/08 13:59	***135***	18/08 11:19	***21***	24/08 16:27	***49***	30/08 15:56	***164***
6/08 20:19	***129***	12/08 20:00	***41***	18/08 17:31	***151***	24/08 23:00	***128***	30/08 21:58	***-6***
				18/08 23:32	***28***				



3.2 BEACH SURVEYS

The physical character of the shoreline was documented at all beaches and at the control plot during the period July 26 to August 14, 1996. Observations or measurements were made of:

- length of suitable beaches
- beach width
- beach slope
- shoreline type and character
- surface and subsurface sediment type and grain size

Length of Suitable Beaches
Most of the intertidal zone at the head of the Van Mijenfjord has significant surface clay deposits and/or has a clay foundation with a top layer of mixed coarse sediment composition (pebble/granule/sand). Beaches were therefore surveyed to ascertain where that coarse sediment layer was greater than 10 cm in order to define which segments or sections of beach might be suitable for the field trials.

Each beach was walked during the low tide interval. Pits were dug in the MITZ (mid intertidal zone) and UITZ (upper intertidal zone) to determine the depth of the coarse sediment layer, i.e., the depth to clay material. Areas with less than 10 cm of coarse sediment were considered unsuitable for the proposed field trials.

Beach Width
Intertidal width was measured from the spring high water mark to the water line at time of the survey. Surveys were timed to coincide with the neap low tide window. This area from the neap low to spring high straddles the MITZ and UITZ and is the zone which is the primary area of interest for experimental use.

The intertidal zone definitions are presented graphically in Figure 2. The lower 1/3, the lower intertidal zone (LITZ), is only exposed on the lowest tides within the lunar tidal cycle. Generally speaking, vulnerability to oiling, oil penetration and retention is relatively low in this zone. The MITZ is both flooded and exposed daily. It is vulnerable to oiling, but also subject to daily tidal washing activity. The UITZ is flooded only during spring tides. Oil deposition, retention and persistence in this upper 1/3 of the intertidal zone is often high for several reasons. With onshore winds, oil accumulates at the beach/water interface, which at high tides is between the bottom and top of the UITZ. Wave action will increase the height of the water

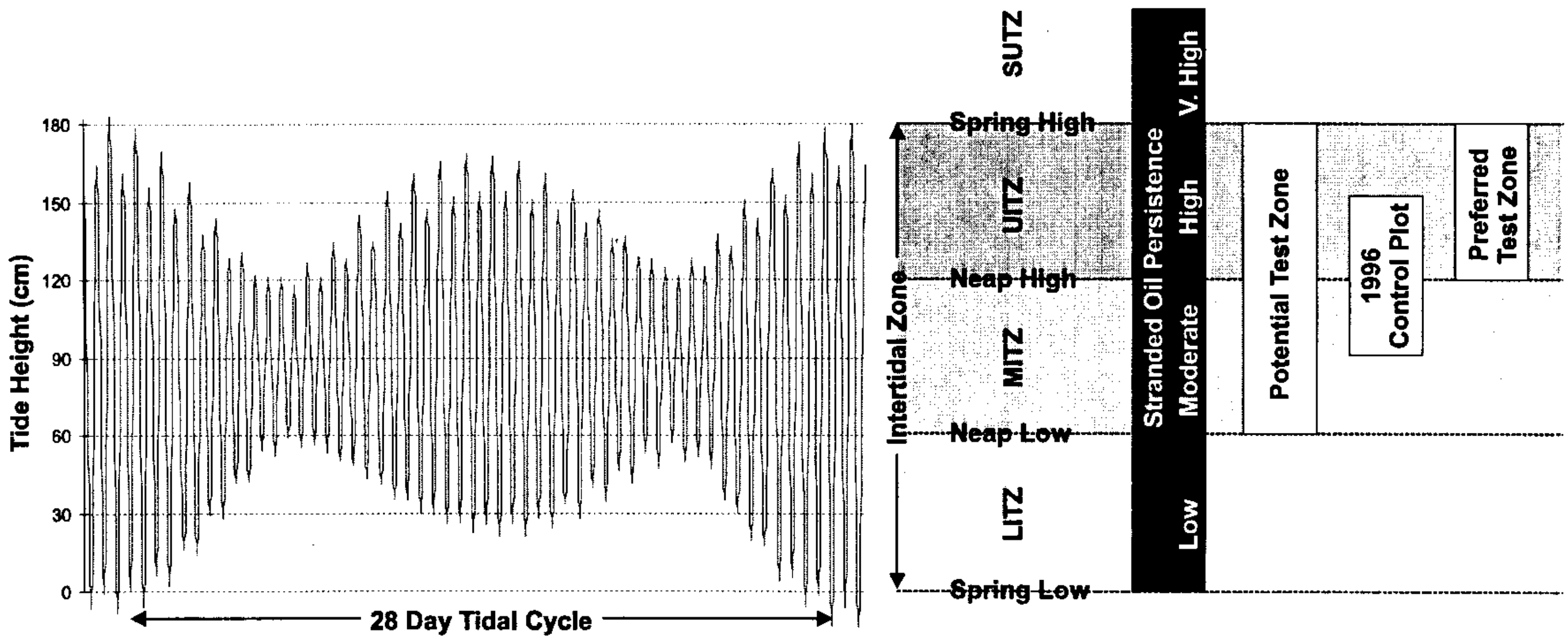


Figure 2. Tidal Zones

line, pushing and depositing oil in the UITZ and supratidal zone (SUTZ). This area receives less cleaning action by tidal washing, and often is the least water-logged or best draining portion of the beach, so that oil penetration into the sediments is least impeded by the presence of interstitial waters.

Beach Slope

In order to determine beach slope, elevation profiles were surveyed across the supratidal and intertidal zones within a "usable or suitable section" of each beach site. A variation of the Emery Profiling method was used (Emery, 1961). The elevation change at fixed intervals of 2 m was recorded by sighting along two graduated rods against a distant horizon. The horizon serves as an approximation of a level reference surface. The accuracy of this technique is suitable for the characterization of beach geometry.

Shoreline Type and Character

Observations were made within the usable length of beach, both alongshore and across-shore on the profiles lines. Observations included backshore type, form, width, and freshwater sources, access by boat and vehicle, intertidal and supratidal features, wave fetch and beach energy level indicators, such as strand lines, storm berms, etc. Alongshore littoral drift was observed at several locations and at different times at Beach #2 by placing a line of painted native pebbles across the intertidal zone. In addition, observations were made at the time of each SCAT survey (Owens & Sergy, 1994) of the control plot of any "off-plot" movement of oil.

Surface and Subsurface Substrate Characterization

Both surface and subsurface sediment type and grain size were described within the area of usable beach. For purposes of this study, a surface sample was defined to include that material from 0-5 cm depth.

Bulk sediment samples each about 3 L in size, were collected for grain size analysis, according to either of the following criteria;

(1) pre-defined depth strata of (a) 0 to 5 cm, (b) 5 to 10 cm, and (c) 10 to 15 cm.
(2) for those sediments which clearly were well sorted and stratified, then the width of the strata was keyed to a change in sediment size, rather than a predetermined depth.

Each sample and each open pit was photographed after sampling. Interstitial water samples also were taken for future oil-fine interaction testing.

All sediment samples were air dried at room temperature and then sieved using 1, 2, 4, 8, 16, 31.5 and 63 mm ASTM-certified sieves. Each fraction was weighed to 0.1 gram. Samples of the material smaller than 1 mm were retained for laboratory studies on oil and fines interaction (part of the Imperial Oil scoping study on OFI). One exception was Site #1, where samples were wet weighed.

In order to provide a direct sediment-size to oil-content comparison, sediment grain size analysis also was carried out on some of the bulk sediment samples that had been collected from the control plot for TPH analysis. Following extraction of oil, these samples were air-dried, sieved, and weighed in the same manner as the un-oiled samples.

Photo Record

Photographs and video-footage of each beach and sediment samples were taken. The control plot was photographed and video-taped from the same perspective prior to sampling.

3.3 DESCRIPTION OF TEST OIL AND PENETRATION TESTING

Test Oil

The test oil used in the field experiment was IF-30, obtained from an Esso refinery in Honningsvåg, Norway. This is the oil that will be used in the full scale experiments in 1997. In addition, IF-30 will be one of the test oils included in other related projects, such as the Beach Basin Trials and the screening study on the factors affecting OFI carried out by Imperial Oil. This use of a single oil will provide a common link between several studies on the in-situ cleanup of oiled shorelines and will facilitate the extrapolation of data from one study to another. All oil was purchased at the same time in order to ensure that the properties of the oil would be identical from one experiment to another.

The physical-chemical properties of the test oil are being analyzed by Environment Canada and will be included in the 'Catalogue of Crude Oil Properties'. Analyses will include density, viscosity, interfacial tension, flash point, hydrocarbon groups and emulsion formation properties. Data presently available are given in the following two tables.

Table 2. Physical Properties of IF-30 Oil

Parameter	Result
API Gravity	18,3
Density (g/mL)	0.9555 (0 degrees C) 0.9437 (15 degrees C)
Dynamic Viscosity (cP)	3506 (0 degrees C) * 757 (15 degrees C)
Kinematic Viscosity (cSt)	3669 (0 degrees C) 802 (15 degrees C)
Pour Point	(-)12 degrees C
Flash Point	86.8 degrees C
Interfacial Tension (dynes/cm)	32.6 (0 degrees C) Air/oil 31.6 (15 degrees C) Air/oil nm** (0 degrees C) Oil/seawater 28.7 (15 degrees C) Oil/seawater nm* (0 degrees C) Oil/fresh water 30.8 (15 degrees C) Oil/fresh water

**flow diagram of viscosity vs. shear rate displays a slight non-Newtonian tendency*
***nm - not measured, under these experimental conditions the instrument/technique can not differentiate between the oil and water.*

Table 3. Simulated Distillation for IF-30 Oil

% Weight vs Boiling Point	
%	BP (C)
5	222
10	262
15	299
20	333
25	363
30	387
35	407
40	425
45	441
50	458
55	475
60	492
65	509
70	528
75	548
80	571
85	597
90	630
95	674

Boiling Point vs % Weight	
BP (C)	%
160	0.9
180	1.9
200	3
250	8.5
300	15.1
350	22.6
400	33
450	47.5
500	62.4
550	75.5
600	85.5
650	92.6
700	97
740	99.1

Oil Penetration Tests

Oil penetration tests were carried out on small test plots (less than 0.25 m^2) near the control plot at the south end of Beach #2. The small tests had two objectives. The first was to achieve a penetration depth of at least 10 cm. This was considered the minimum experimental working depth for experimental treatments. The second was to apply the minimum amount of oil required to saturate the sediment so that an excessive amount of oil would not be lost on the following high tides. To achieve this, the oil had to be sufficiently fluid to penetrate to the required depth, yet adhesive enough not be lifted off the sediment after the first few tides. In order to optimise the oil retention and penetration in the sediment, a number of parameters were considered in these tests, including:

- oil loading
- number of applications
- oil viscosity

3.4 OILING PROCEDURES AND CONTROL

The plot was oiled using a prototype discharge system. This consisted of a 1.25 m long polyethylene pipe with a diameter of approximately 3 cm, perforated with a single line of 3mm holes every 3 cm (about 40 holes). Oil was pumped from the drums with a small gear pump at a rate of approximately 12 L/min.

Oil on site was stored in 200 L drums, contained inside a plastic-lined wooden berm, capable of containing 110% of the stored volume. In case of a large leak or spill within the bermed area the the oil could be pumped from the berm into empty drums. Sorbent material was on hand to collected any accidentally spilled oil.

The oil loading was matched to the sediment conditions of the shoreline by pre-spill testing and calculations of penetration and retention. This minimises oil loss through runoff and tidal washing and reduces the total quantities of oil released.

Oiling of the control plot was carried out in a controlled manner, with the necessary response equipment in place. Loss of oil from the test area was controlled by deploying booms around the control plot as shown in Figure 3. Booms were deployed at high tide, and were in place before application of the oil commenced. The test plot was boomed during the entire oiling operation. Sorbent booms were deployed along the inside and outside perimeter of the conventional harbour boom.

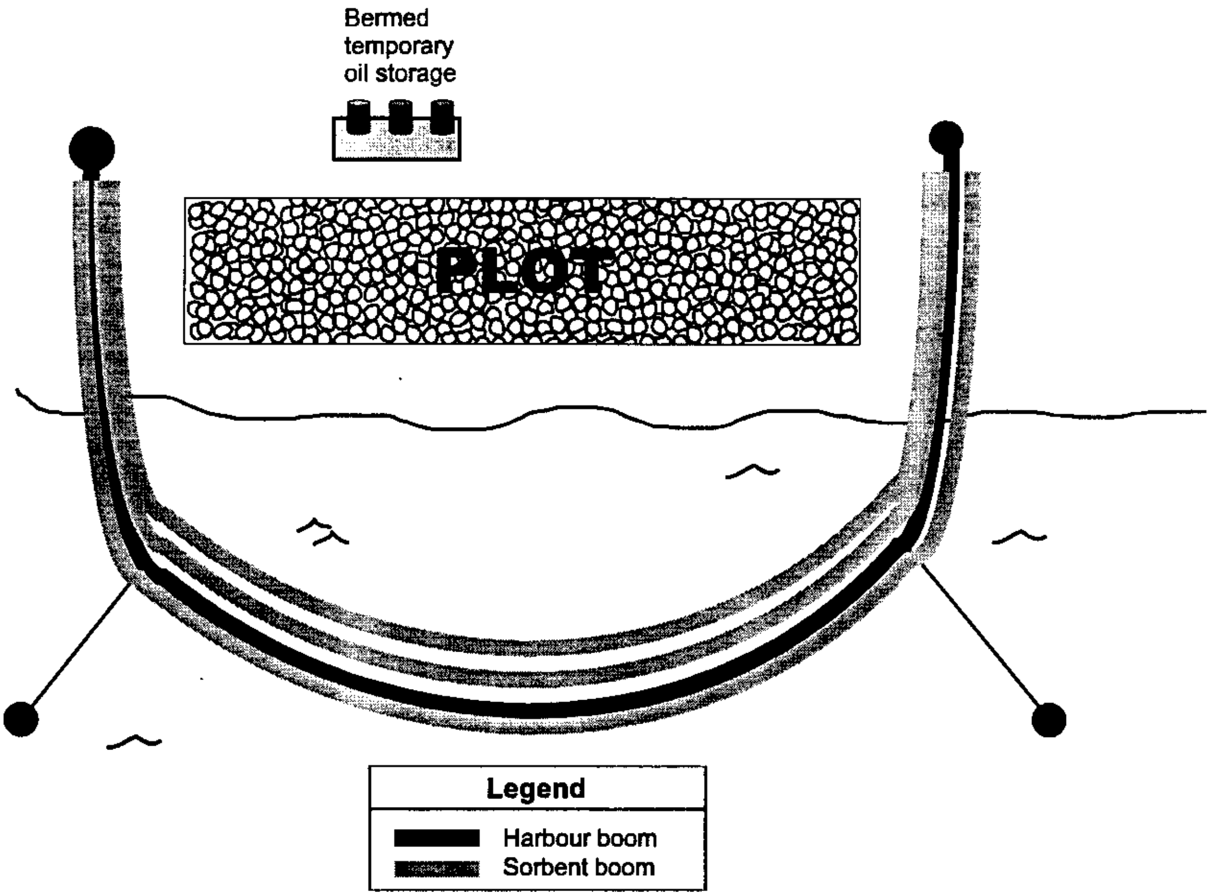


Figure 3. Layout of Oil Control Booms Around Control Plot

A double layer of sorbent boom was placed inside the harbour boom, following the suggestion of the Governor of Spitsbergen's Environmental Officer. Although not required longer than 4 days post-spill, the conventional boom remained in place for a period of 10 days. The sorbent booms were kept in place to recover any sheen for as long as necessary and were removed after 14 days.

A portable skimmer, a *Desmi Mini-Max*, was on hand and ready for deployment in the event of an uncontrolled release of oil. This skimmer is a centre float weir skimmer with a recovery rate of up to 35 m^3/hr on light to medium viscosity oils. This skimmer could be easily deployed from the crane of the work boat inside the boom. Temporarily storage was available on site and on board the boat for oil and water recovered with the skimmer. A 25 L/min pump and generator to run the pump were also installed on board the work boat to regularly transfer oil to drums.

Plate 1

Oiling the Plot 02/08/96

Oiled Plot Immediately after Oiling

Aerial of Oiled Plot on First Rising Tide

3.5 OILING AND MONITORING OF THE CONTROL PLOT

The 1996 control plot was selected at the south of Beach #2. A total of 560 L of oil was applied to the control plot on August 2, 1996. The oil was applied under very calm conditions: the wind speed was less than 1 m/s and there was almost no wave action. A diagram of the oiled control plot is given in Figure 4. The total dimensions of the oiled area are 5 m in width by 23 m in length. The oil loading over this area was 4.9 L per square meter.

In order to minimize anticipated edge effects, the outside margins of the oiled area were not included in the area to be monitored or surveyed. This buffer zone included 50 cm at both the top and bottom of the plot, and 1 m to the south and 2 m to the north at the ends of the plot. The actual experimental sampling area therefore was 4 m by 20 m. This was subdivided into ten blocks each measuring 2 m by 4 m.

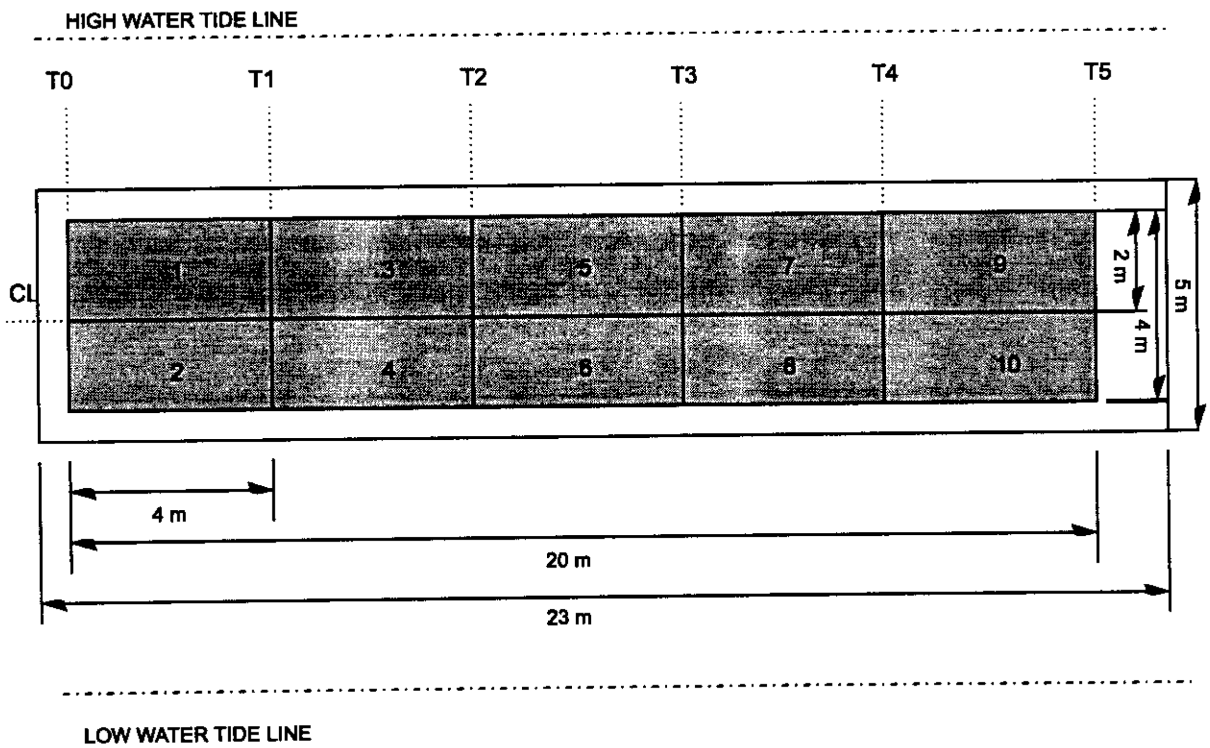


Figure 4. Control Plot Layout
Sampling blocs are numbered 1 to 10, transect lines are numbered T0 to T5 and the center-line is denoted as CL. The shaded area indicates the area from which samples were taken.

The chronology of events for the oiling, sampling, and observation of the control plot is summarized in Table 4.

Table 4. Summary of the Control Plot Experiment

Date	# of days (from oiling)	Sample Type	Observations
02.08.96	0	oiled plot	
03.08.96	1	SCAT survey	
04.08.96	2	SCAT survey	
05.08.96	3	SCAT, + sediments	Storm overnight
06.08.96	4	SCAT survey	
14.08.96	12	SCAT, + sediments	
16.08.96	14	SCAT survey	

Plot observations and sampling were conducted between one to two hours before and after the predicted low tide.

During each survey, the following was noted or recorded:

1. Environmental conditions: the wind speed, temperature, cloud cover, precipitation, tidal level and wave height at the time of sampling.
2. Wildlife obervations.
3. Sketches were drawn of the entire plot and general oil cover inside and outside of the plot.
4. Visual estimation of oil cover in each bloc of the plot.
5. Littoral drift: this was estimated by noting the distance oiled sediment had drifted from the plot. In addition, the movement of spray painted pebbles, which were placed in a line across the plot, were also observed.
6. Photographic and video documentation: prior to sampling, the entire plot was photographed and videotaped. Close-up photographs of the oiled sediment in each individual bloc also were taken.
7. Depth of penetration: In each bloc a pit was dug and the depth to which the oil had penetrated was recorded, as well as the distribution of the oil within the sediment.
8. Bulk sediment sampling: samples were taken from each bloc for total petroleum hydrocarbon and grain size analysis.

There were two basic types of surveys. The first type included visual SCAT measurements and photo and video records, which were used to document changes in oil behaviour over time, in particular (a) oil distribution and (b) depth of penetration. The second involved a systematic sampling of sediments, from within the plot, which was used for (a) testing of the bulk sediment sample and extraction protocols and (b) quantificatiion of oil in the sediments by TPH analysis.

Observations of Oil Behaviour on the Control Plot

A description of oil penetration and surface cover was recorded using systematic procedures outlined in Owens and Sergy (1994) and typically used in SCAT surveys.

Oil cover/distribution observations of the control plot were conducted 6 times over the course of the experiment, starting one day after oiling. Some of the surveys coincided with the TPH sampling. Visual estimates of oil cover were made within each of the ten blocs within the plot, from a point along the centre line of the plot (see Figure 4).

Oil penetration was observed by digging pits on four occasions, and observations included those pits that had been dug during sediment sampling for TPH analysis. The presence, absence, layering, etc., of any subsurface oil was visually recorded. Pits were marked so that they would not be re-sampled.

At the same time as the sampling at each of four fixed locations within the plot, close-up (approx. 1 m height) colour photography and video were taken with the same photo scale and plot location, with date information in the bottom photo frame.

Oil in Sediment Quantification

Following a period of stabilisation of the oil on the control plot, bulk sediment samples were collected for oil extraction and analysis to determine TPH. The oil in the beach sediments was judged to be relatively stable within 48 hours of oiling, by which time no black oil and only sheen was being refloated and released from the sediments. Samples of oiled sediments were collected on two occasions, August 5 and August 14. A sample was collected from within each of the defined 10 blocs and the location recorded as indicated in Figures 5 and 6.

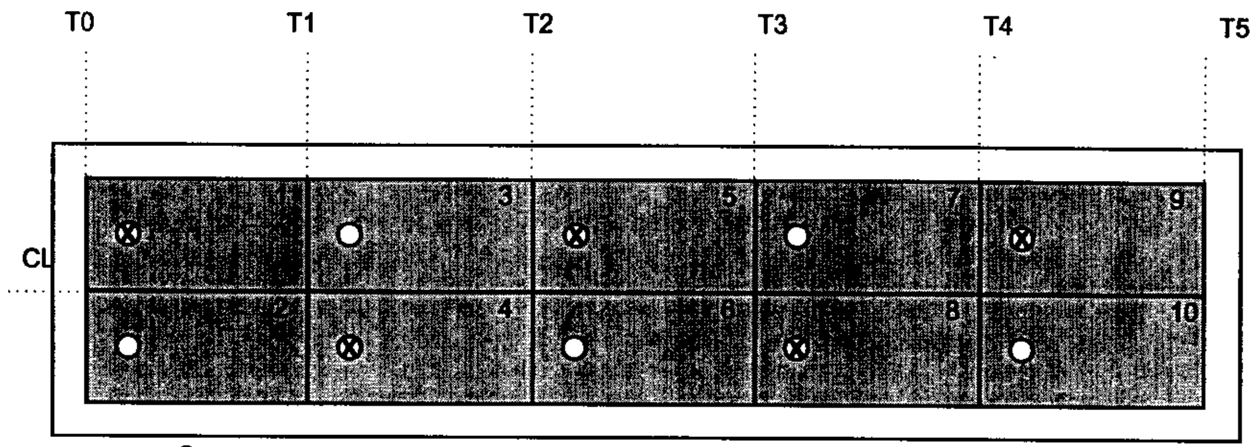


Figure 5. Sampling Strategy
First Sample Period:
August 5, 1996

○ = sample locations where surface samples were taken

⊗ = sample locations where surface and sub-surface samples were taken

sample period 1

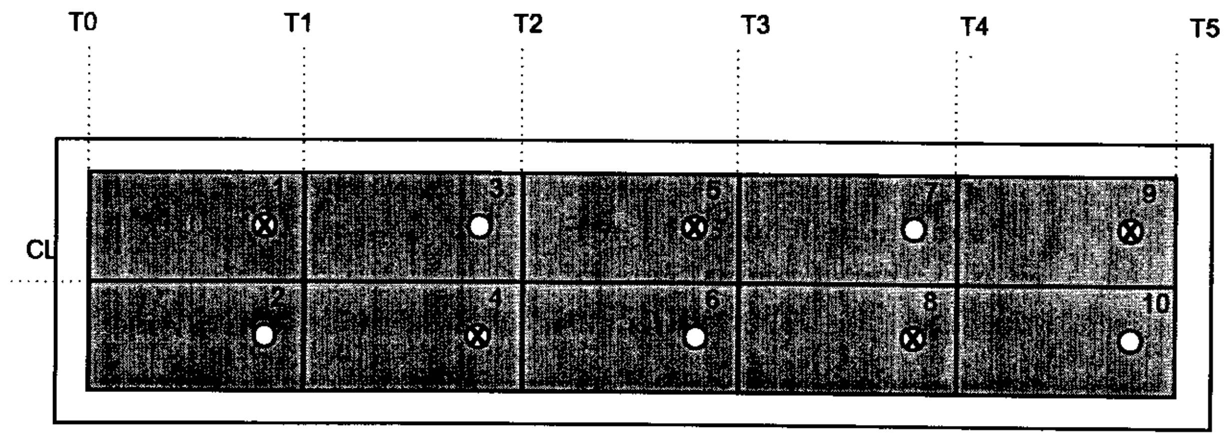


Figure 6. Sampling Strategy
Second Sample Period:
August 14, 1996

○ = sample locations where surface samples were taken

⊗ = sample locations where surface and sub-surface samples were taken

sample period 2

A total of 35 bulk sediment samples were collected from the control plot. The oil was extracted from these according to the protocol described in Section 3.6. These samples were analysed using TPH (Total Petroleum Hydrocarbons) methods at Environment Canada laboratories in Ottawa (Wang et al., 1994a,b,c; Wang & Fingas, 1995; Wang et al., 1995).

Both surface and subsurface samples were collected at the same location. When present, the surface clast layer of scattered pebbles was scraped from the sampling area prior to sampling. Depth 0 is defined as the underside of this pebble layer. A surface sample is defined as that material from 0 to 5 cm depth. A subsurface sample included that material greater than 5 cm below the surface.

Most of the samples were then taken from the following intervals: surface to 5 cm, 5 to 10 cm and 10 to 15 cm, or to visible depth of oiling i.e. to the bottom of the oiled zone. This last value was recorded as maximum penetration depth. Below this zone the sediment material was visually oil free.

A metal ring encircling a surface area of 600 cm^2 was placed over the area to be sampled to facilitate removal of a specific volume. As the sediment was removed the ring was inserted into the pit to prevent sediment from the wall of the pit from falling into the pit being sampled. The samples were approximately 3000 cm^3 in volume.

The sediment samples were placed in pre-labelled plastic bags and taken to the laboratory for extraction.

3.6 PROCEDURES FOR BULK SAMPLE HC EXTRACTION AND ANALYSIS

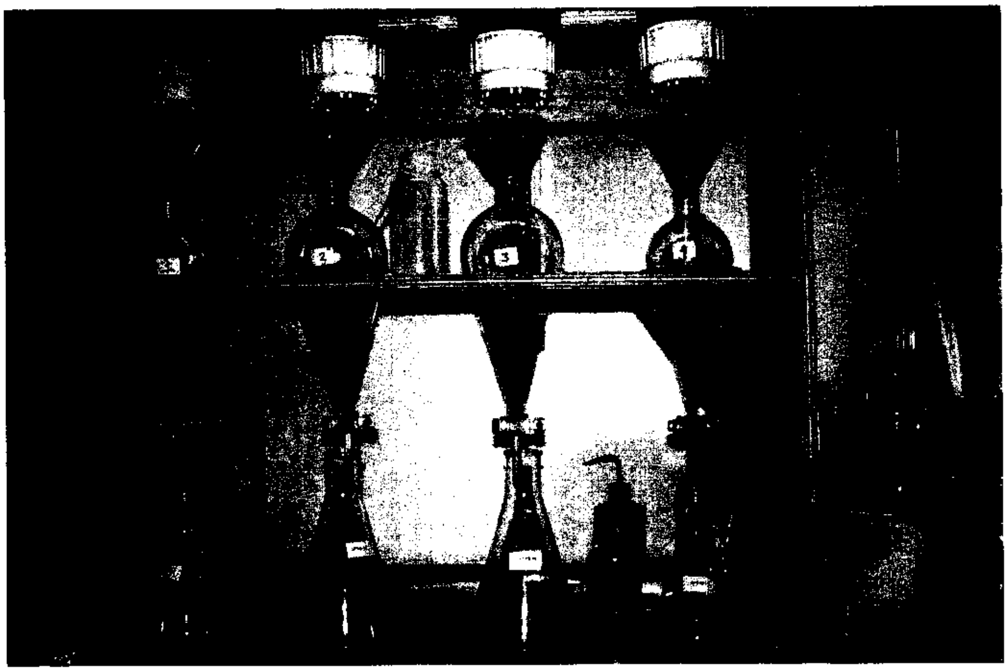
A bulk sediment extraction protocol recently developed for laboratory use in another Environment Canada/Imperial Oil project was tested and modified for field use during the field program in Sveagruva.

Oiled sediment samples from the control plot were treated according to this protocol. From the resultant oil-in-DCM extract, four identical samples in 20 ml vials were collected. Two vials were sent to Environment Canada laboratories for TPH analysis. One set of vials is being archived in Environment Canada and the other in SINTEF laboratories.

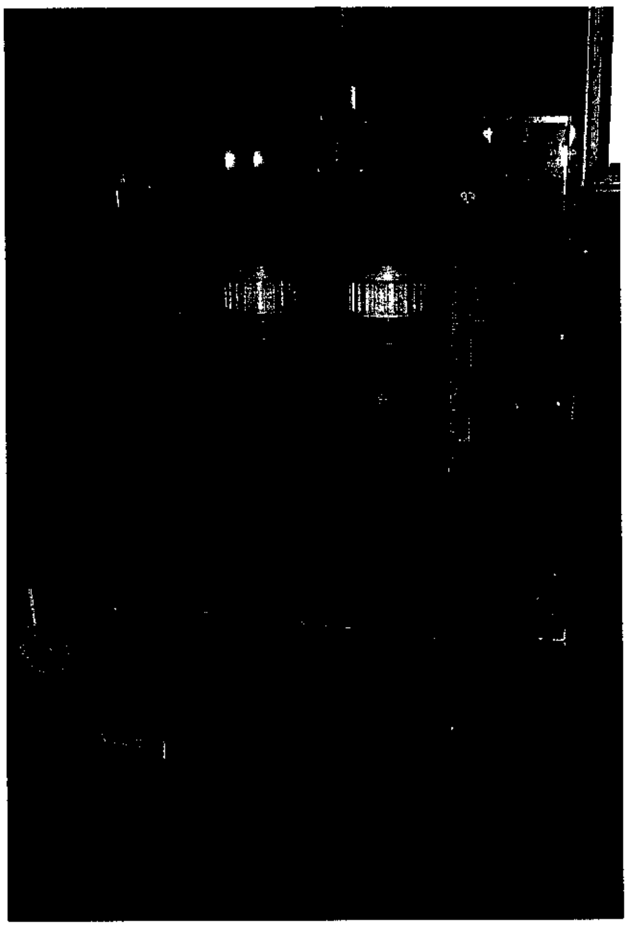
The bulk sediment extraction procedure developed and used during the 1996 field survey had the following component steps.

1. Weigh oiled-sample in plastic bag (or if collected in a tin then tare the tin).
2. Pour sample into 4 L high density polyethylene (HDPE) heavy-duty bottles with 83mm polypropylene screw caps retrofitted with drain plugs.
3. Add 150 to 200 mL of Dichloromethane (DCM). Record actual volume used.
4. Put cap on carboy and shake for 3 to 5 min total using a paint shaker or shaker table. Loosen cap to release pressure, re-tighten.
5. Remove drain plug as required. Drain extract from carboy into 1L separator funnel via a wide mouth glass funnel. Loosen cap very slightly to allow air into carboy.
6. REPEAT step #3 a minimum of three time or until extract is relatively "clean". Clean was visually defined against a colour standard (pale yellow). Leave last drain until well drained. Record actual volume of DCM used each time.
7. Rinse lids, funnel, etc. with DCM and add to separator funnel.
8. Swirl separator funnel and leave to settle until a defined interface is visible in the separatory funnel (if water present).
9. Draw DCM extract layer down into a clean pre-weighed Erlenmeyer flask (or when separatory funnel is otherwise full). Rinse separatory funnel with DCM and add to Erlenmeyer flask.
10. Weigh Erlenmeyer plus extract.
11. Weigh labelled sample vials.
12. Weigh sample vials plus lids.
13. Fill four vials using a glass pipette and crimp vials immediately. (Mix extract before taking samples due to partitioning).
14. Weigh filled vials.
15. Draw water out of separatory funnel into pre-weighed beaker, and weigh.

Plate 2



Draining Extract from 4 L Nalgene Bottles to Separatory Funnels



Paint Shaker with Bottles

4.0 RESULTS

4.1 BEACH SURVEYS

Beaches #1, 2 and 3 all have clay-based moraine hills in the immediate backshore. Much of the intertidal zone has clay patches at the surface and all of the intertidal zone would appear to have a clay foundation with a layer of coarse sediment on top. Beaches were therefore surveyed to ascertain where that coarse sediment layer was greater than 10 cm to define what might be suitable and usable segments or sections for the field tests. "Usable" or "suitable" beach in this report therefore refers to sections or segments of the coast that were surveyed that meet the experimental selection criteria.

4.1.1 Beach #1

Beach #1 extends from the Kapp Amsterdam road access point to "Moraine Point" (See Figure 7). The entire northerly section has extensive mudflats which are exposed at low tide. Water deepens slightly toward the south end up to Moraine Point. Even at this promontory, a very shallow mud-bottomed subtidal zone extends 50 m offshore.

For most of Beach #1, there is less than 10 cm of coarse sediment in the MITZ/UITZ. The clay base here is very shallow. There is one section of usable beach at the far south end (Moraine Point) where sediment depth was considered adequate.

The usable intertidal zone is a continuous segment about 70-80 m alongshore. This area falls between P1 and P2 profiles (see Figure 8). A little additional distance could be obtained by moving further south along the shoreline, however, wave exposure changes rapidly when rounding the corner of the point. The intertidal zone backs on to steep-faced clay bluffs (moraines). Basically there is no usable backshore, and no access from the backshore. Small boat access is possible but awkward. ATVs (All Terrain Vehicles) could be used from the Kapp Amsterdam access road or from Beach #2 (if allowed by permit). Large vehicle access is not likely. The fetch window is about 45 degrees, with a fetch of about 3 km to the north. This is the lowest wave energy beach of those surveyed.

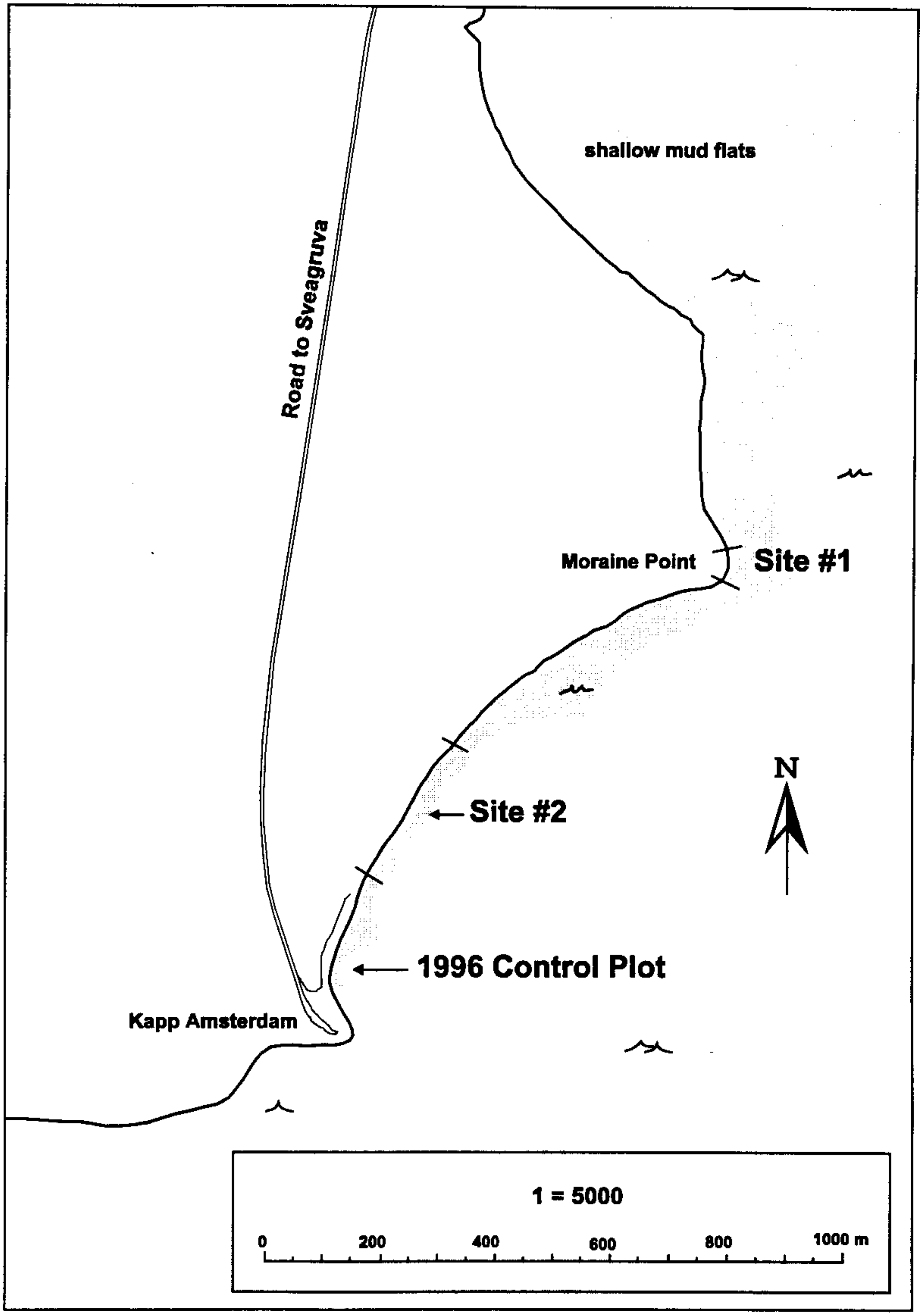


Figure 7. Overview of Beaches #1 and #2

The MITZ/UITZ width (spring high line to the low neap tide) is approximately 6 to 7 m. This width was measured on August 8, 1996, at which time the low tide height was 50 cm. This beach face has a consistent slope of 16.5 degrees.

Within the MITZ/UITZ, the sediments are a visually consistant mixture of small pebble/granule/sand. The top 10 cm layer is dominated by 1 to 8 mm material (see Table 5). A higher percentage of larger pebbles could be found in deeper subsurface sediments. The lack of fine sand/clays from the grain size analysis is a function of the wet seiving technique that was used for this site only. Visually, the sediments contained relatively little clay material. The spring high water line was delineated by small storm berms which abut the backshore bluff. The berms are 1 m to 1.5 m wide, and composed of 2 to 4 cm pebbles over sandy gravel. The pebble fraction is typically angular or sub-rounded. Below the low neap tide level, the substrate changes dramatically to a flatter sloped mud/silt/sand.

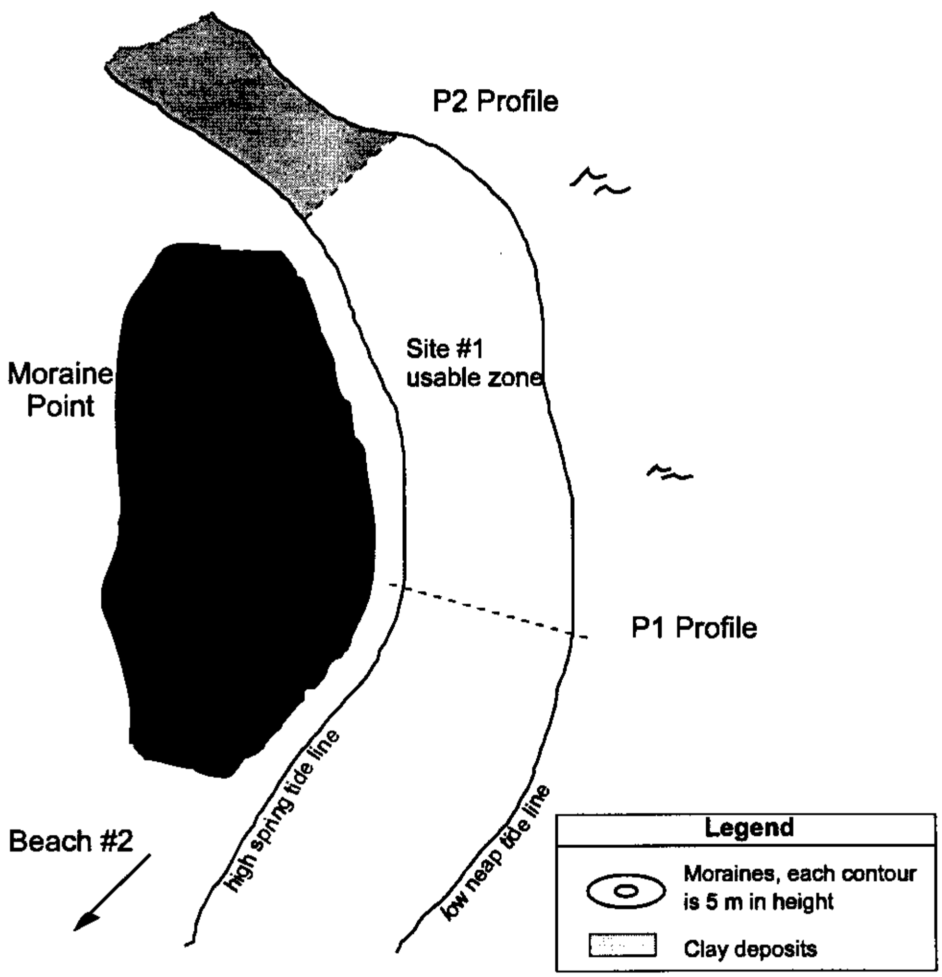


Figure 8. Site #1

Plate 3

Beach #1: Potential Experimental Site #1

Closeup of Intertidal Sediments at Site #1

4.1.2 Beach #2

Beach #2 is the most suitable candidate beach for the 1997 experiments, and was therefore surveyed most extensively. This beach stretches from Moraine Point to Kapp Amsterdam, a distance of about 1 km (see Figure 7). Along this length it is relatively straight and has a fetch window of about 120^{o}, with a 14 km exposure to the SE and 6 km to the SW. It is the second lowest wave-energy area of those examined and, for this region, would be classed as a medium wave-energy environment. The painted surface clast layer of pebbles was observed to move 4 to 16 m to either side of their origin during a period of several days.

Boat access is awkward due to the relatively shallow subtidal shelf which extends about 50 m offshore. Nevertheless, access can be obtained by small boat at any time, or by a larger vessel during high tide. The site has road / vehicle access from the south end (a gravel excavation area) to a point near the beginning of the usable beach sections. From this point it is ATV accessible to the far end of the usable beach (up to marker #8), a distance of about 400 m. ATV access is possible by driving on the flat SUTZ bench. Access via the backshore is possible by traversing the tundra between the moraines, if allowed by permit.

Sections of usable beach within Beach #2 are shown in Figure 9. Location markers were placed every 50 m from the edge of the gravel excavation area. The main usable segment exists between marker 5 and 8, a length of approximately 145 m. There is also a 40 m segment between 0 and 1. Between marker 1 and 2, there are also much smaller (10 to 20 m) segments positioned between patches of clay. This area is backed by a small standing pond of water about 10 m behind the storm berm. Between markers 3 and 5, clay base could be found about 10 cm below the surface. Between 6 and 7 there were some patches of clay but these were 15 to 18 cm below the surface and therefore considered beyond the zone that would impede oil penetration.

The beach was surveyed on August 7 on a low tide with a tide height of 45 cm. The shoreline was profiled at three locations (P1, P2 and P3 on Figure 9) within the 145 m long usable segment and the sediment sampled at three elevations along each profiles. Sample sites were below the spring high and above the neap low tide lines (i.e., the potential test zone). At each point, samples were taken of surface and subsurface sediments, (0 to 5 cm, 5 to 10 cm, and 10 to 15 cm). A total of 25 samples were collected for grain size analysis (Table 5).

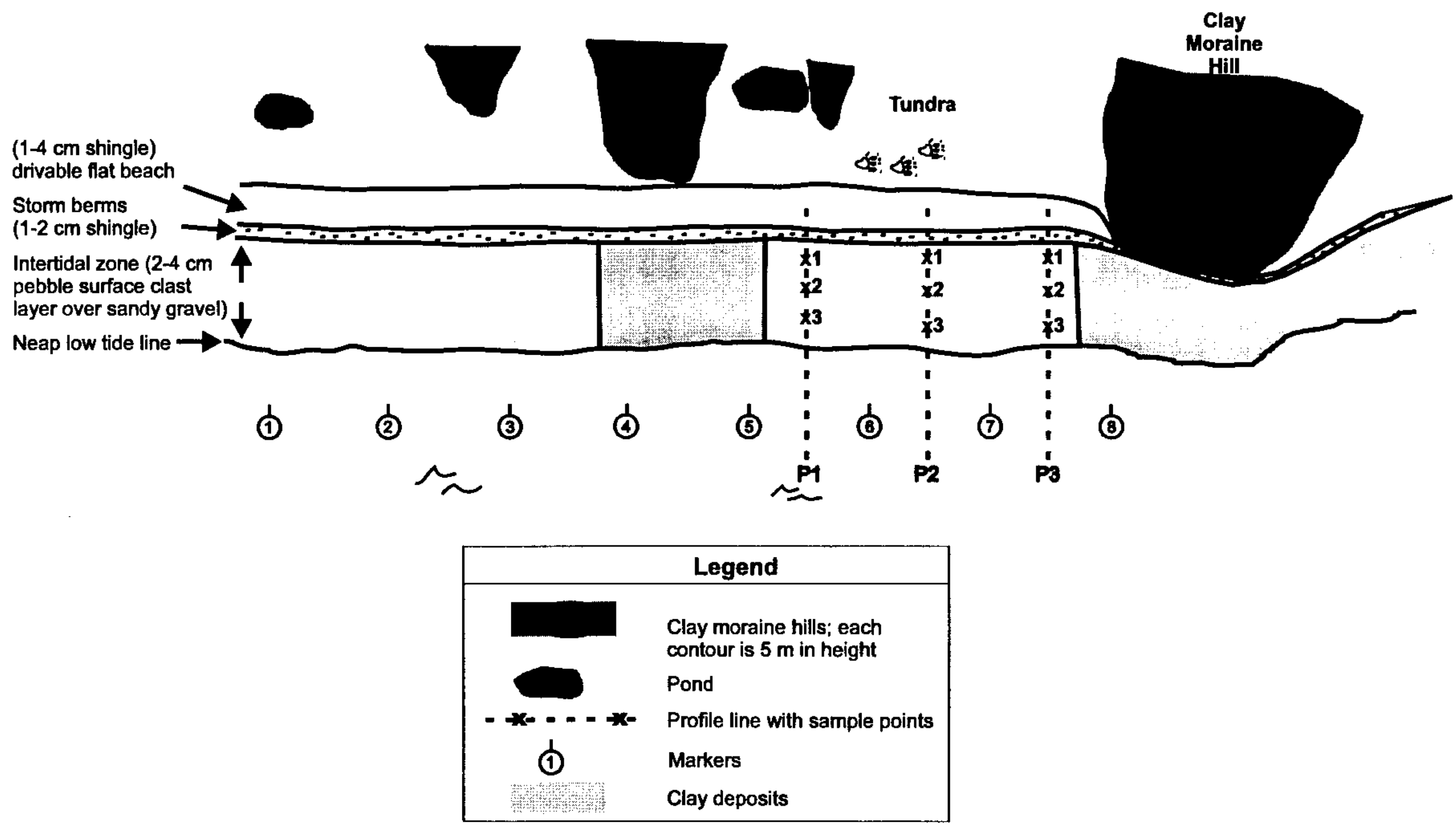


Figure 9. Site #2

Plate 4

Overview of Beach #2: Lookir towards Kapp Amsterdam

Beach #2:
Potential Experimental Site #.

Closeup of Intertidal Sediments at Site #2

Table 5. Grain Size Analysis of Sites #1 to 4

Sample	Depth in cm	Intertidal Location	% Grain Size in mm								
Site 1			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S1-P1-2A	0-10	neap high	0.0	0.0	1.5	6.4	17.3	39.6	35.2	0.0	100.0
S1-P1-2B	20-30	neap high	0.0	5.5	15.6	18.2	22.0	22.5	16.1	0.0	100.0
S1-Px-2A	0-10	neap high	0.0	0.0	5.6	12.6	21.3	40.1	20.4	0.0	100.0
S1-P2-2A	0-10	neap high	0.0	4.8	8.3	9.7	21.8	26.7	28.6	0.0	100.0
Site 3			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S3-P1-1A	0-20	mid UITZ	0.0	2.7	7.4	23.6	30.5	20.9	11.0	3.8	100.0
S3-P1-2A	0-20	mid LITZ	11.1	5.4	15.0	19.8	18.0	12.4	7.8	10.5	100.0
Site 4			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S4-P1-1A	0-20	bot UITZ	0.0	0.9	8.3	15.3	26.6	26.1	14.6	8.2	100.0
S4-P1-1B	20-40	bot UITZ	0.0	0.0	3.3	7.8	13.1	21.1	24.0	30.6	100.0
S4-P1-2A	0-20	top MITZ	0.0	0.0	6.9	14.0	17.0	21.0	19.7	21.4	100.0
S4-P1-3A	0-20	bot MITZ	0.0	0.0	14.9	8.6	13.9	14.6	17.2	30.7	100.0
Site 2 Profile 1			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S2-P1-1A	0-5	mid UITZ	0.0	10.6	14.3	11.4	9.8	16.9	24.0	13.1	100.0
S2-P1-1B	5-10	mid UITZ	0.0	0.0	7.8	10.0	11.8	20.3	31.6	18.5	100.0
S2-P1-1C	10-15	mid UITZ	0.0	0.0	9.5	5.6	16.7	34.5	17.4	16.3	100.0
S2-P1-2A	0-5	top MITZ	0.0	0.0	15.4	9.9	8.8	11.0	13.3	41.7	100.0
S2-P1-2B	5-10	top MITZ	0.0	8.8	34.2	16.0	8.7	7.2	9.9	15.2	100.0
S2-P1-2C	10-15	top MITZ	0.0	17.0	17.9	16.1	11.4	9.4	7.8	20.3	100.0
S2-P1-3A	0-5	bot MITZ	0.0	0.0	27.0	11.3	7.5	7.3	16.8	30.1	100.0
S2-P1-3B	10-15	bot MITZ	0.0	12.4	17.3	7.1	9.2	8.6	13.1	32.3	100.0
Site 2 Profile 2			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S2-P2-1A	0-5	mid UITZ	0.0	12.1	8.6	7.2	12.4	21.0	24.1	14.5	100.0
S2-P2-1B	5-10	mid UITZ	0.0	0.0	4.2	13.2	26.0	24.6	18.5	13.5	100.0
S2-P2-1C	10-15	mid UITZ	0.0	7.3	12.3	15.1	20.9	15.0	14.3	15.0	100.0
S2-P2-2A	0-5	top MITZ	0.0	2.5	15.6	11.6	9.6	13.9	22.4	24.4	100.0
S2-P2-2B	5-10	top MITZ	0.0	4.1	17.8	15.6	11.5	11.7	15.7	23.6	100.0
S2-P2-2C	10-15	top MITZ	0.0	0.0	9.6	23.2	15.5	12.4	19.1	20.2	100.0
S2-P2-3A	0-5	bot MITZ	0.0	10.3	21.0	8.6	9.7	18.6	20.1	11.7	100.0
S2-P2-3B	5-10	bot MITZ	0.0	0.0	31.7	13.6	9.4	10.8	13.9	20.6	100.0
S2-P2-3C	10-15	bot MITZ	0.0	18.6	28.1	14.6	5.5	7.5	12.5	13.2	100.0
Site 2 Profile 3			>63	>31.5	>16	>8	>4	>2	>1	<1	Total
S2-P3-1A	0-5	mid UITZ	0.0	6.3	11.3	20.0	13.2	10.5	19.4	19.2	100.0
S2-P3-1B	5-10	mid UITZ	0.0	0.6	14.2	14.6	15.7	8.7	17.4	28.9	100.0
S2-P3-1C	10-15	mid UITZ	0.0	9.6	21.7	22.0	16.1	11.4	10.1	9.0	100.0
S2-P3-2A	0-5	top MITZ	0.0	3.1	8.3	9.7	10.0	13.7	19.4	35.8	100.0
S2-P3-2C	10-15	top MITZ	0.0	0.0	8.0	18.5	14.4	15.7	17.9	25.6	100.0
S2-P3-3A	0-5	bot MITZ	0.0	3.1	15.3	13.1	16.0	24.5	18.9	9.0	100.0
S2-P3-3B	5-10	bot MITZ	0.0	5.5	17.4	14.8	12.1	11.6	16.9	21.6	100.0
S2-P3-3C	10-15	bot MITZ	0.0	21.1	26.6	7.7	5.7	8.6	12.2	18.2	100.0

Sample Code:

e.g. S2 - P3 - 3C = Site 2 - Profile3 - Sample3 Depth C

The LITZ is dominated by muds and clays. The MITZ/UITZ width is on the order of 7 m wide and is a classic gravel (sand/pebble) beach. MITZ/UITZ beach slope is relatively consistent. The average slope of the three profiles is 16.5 degrees.

Despite intra-sample variations, the beach sediments sampled on Beach #2 are relatively consistent in character. In terms of sediment size, the sediments are predominantly in the pebble size range with a secondary sand fraction. No cobbles (>64 mm) were found in any of the samples collected on this beach. The data for Beach #2 in Table 5 can be summarized as follows:

1) Pebbles constitute
   >30% of the sediments by weight in all of the 25 samples,
   >40% in 20 samples, and
   >50% in 9 samples.
2) Sands (<2.0 mm) constitute
   >30% in 20 samples,
   >40% in 10 samples, and
   >50% in 3 samples.
3) Sands (<1.0 mm) occur in all samples and account for:
   >30% in 5 samples,
   >40% in 5 samples, and
   >50% in none of the samples.

In terms of alongshore variation between the three profiles there are no significant changes evident from the data. The only variation that can be detected is a slight fining of the surface (0 to 5 cm) coarse fraction on profile 3 as compared to the other two profiles.

In term of across-shore variation on the three profiles, the UITZ and lower MITZ are more similar as compared to the upper MITZ, as the latter generally has a smaller surface pebble fraction and a higher surface sand fraction than the other two bands.

In terms of differences with depth, the surface pebble layer was coarser than those pebbles in the samples collected at > 5 cm, in only two of the 9 sample locations (P1-1A and P1-3A). The only other discernable change occurs with a decrease in the sand fraction with depth (when comparing the 0 to10 cm and the 10 to 15 cm depth ranges) in the UITZ samples, but no discernable such change was noted with depth in the two MITZ bands.

4.1.3 Beach #3

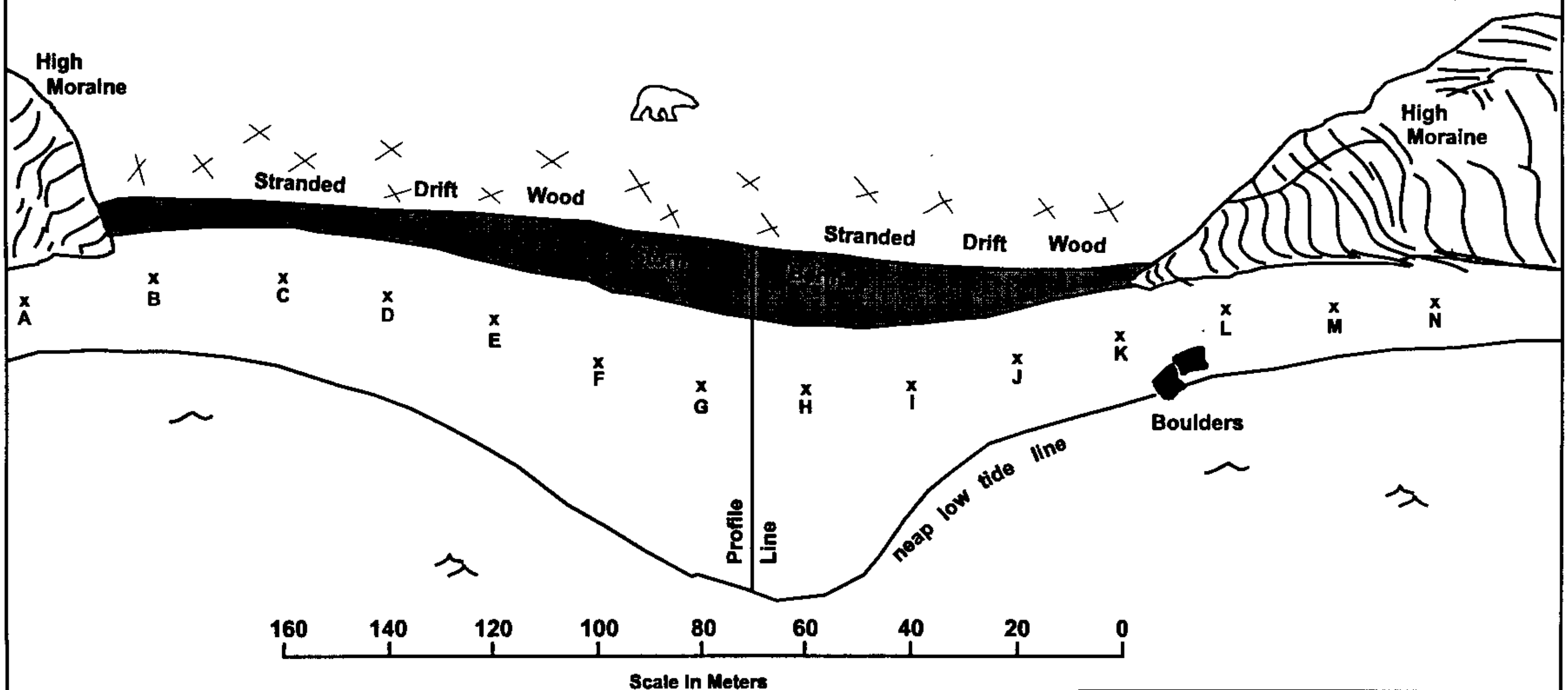
Beach #3 begins at Kapp Amsterdamn and extends for about 1 km towards the fjiord entrance. The majority of the intertidal zone in this stretch is backed by clay moraine bluffs. Road access exists to Kapp Amsterdam, thereafter, overland access is possible but difficult in most places due to the backshore moraine. These features also limit ground transport over the intertidal zone except at low tide. Access by sea is possible along the entire reach. The water depth is adequate to bring a sea truck to shore even at low tide. .

Short (20 to 50 m) segments of usable beach are sporadically spaced along Beach #3. Sediments were similar to those described for site #3 below, and generally have a relatively uniform distribution of size ranges from large pebbles to fine sands, with visible clay content. In some cases these mixed sediments were overlain by a discrete surface band of well-sorted sediments in the size range 2 to 8 mm (granule and very small pebbles).

The best potential site (test site #3) is located at the far end of beach #3 and approximately 1 km from Kapp Amsterdam. As shown in Figure 10, it is a small point of shoreline with a longer continuous segment of usable beach than the rest of those in found along beach #3. This section is flanked by moraine bluffs but the backshore is an open tundra bowl. A large accumulation of driftwood and multiple large shingle storm berms would indicate this section to be of relatively high energy. The fetch window is about 120° with open exposure toward the mouth of the fiord and open sea some 40 km away.

The site was surveyed on August 9. The MITZ/UITZ width is about 8 m and the beach slope on the profile is 16.7 degrees. Visually, the sediments appeared more heterogenous than other beaches. Generally they were an uniform assortment of all grain sizes. Clay content varied visually and increased towards the flank of the point (profile). In the UITZ extending to each side of the profile, there was a 20 cm layer of sorted sediment in the 2 to 8 mm range.

Site #3 was long enough to support two adjacent plots.

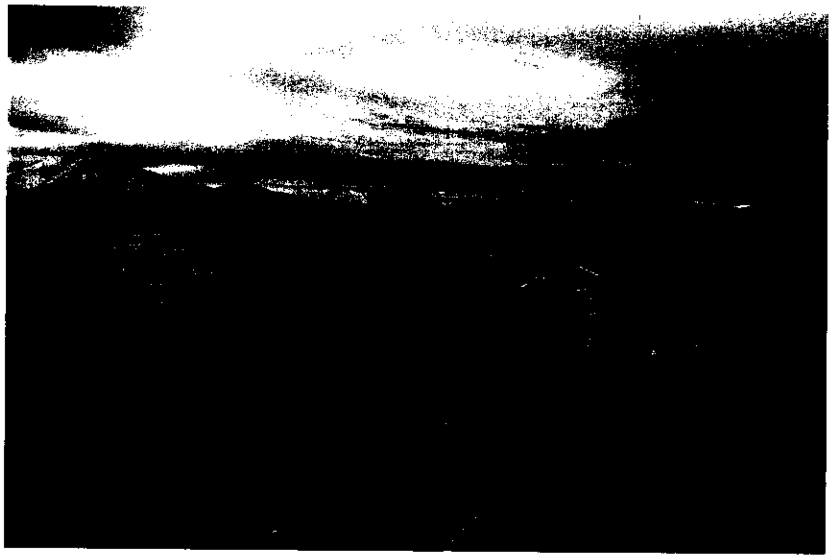


Observations at Neap High

	Surface	Subsurface
A	cs, p	clay > 5 cm
B	cs, p	clay > 5 cm
C	g	clay > 7 cm
D	g	gravel; clay > 10 cm
E	g	gravel
F	g	cs, p
G	g	cs, p
H	g	cs, p
I	g	cs, p
J	cs, p	cs, p
K	cs, p	cs, p
L	cs, p	clay > 5 cm
M	cs, p	clay > 10 cm
N	cs, p	clay > 10 cm

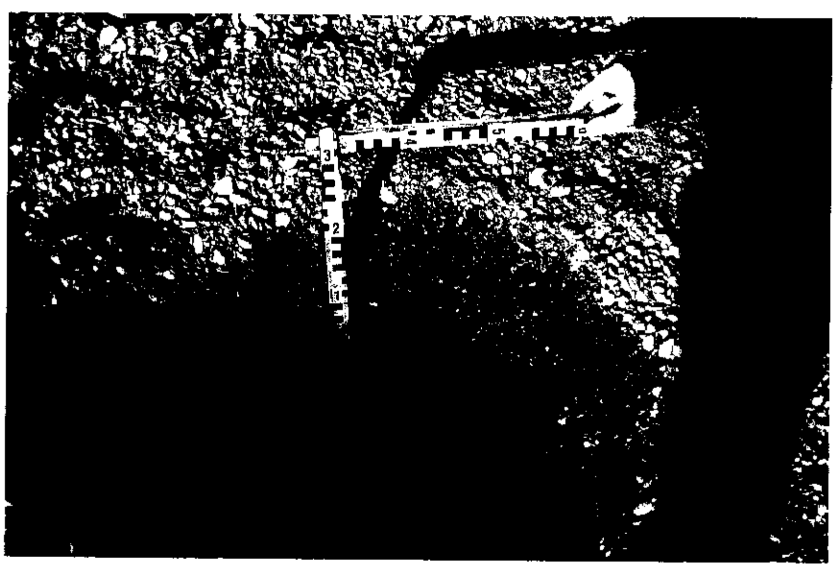
Figure 10. Site #3

Plate 5



Beach #3:
Potential Experimental Site #3

Beach #4:
Potential Experimental Site #4



Closeup of Intertidal
Sediments at Site #4

4.1.4 Beach #4

Beach # 4 is located near the lagoon (see Figure 1) and detailed in Figure 11. It is a 1.5 km straight section of shoreline, all of which is usable. No clay deposits were found. There is no access by land but the nearshore drops off very quickly making boat access relatively easy. It is an exposed beach with a long fetch to the mouth of the fiord some 40 km south, however, wave energy is deflected or broken partly by the point at Kapp Amsterdam.

The site was surveyed August 10 on a low tide height of 53 cm. The entire length of Site #4 has multiple storm ridges of 2 to 8 cm shingle, backed by a wide zone of driftwood deposit and a flat and open backshore. The UITZ/MITZ is about 8 m wide with a slope of about 19 degrees. Alongshore the entire length of the beach, the sediments are relatively homogenous. Some stratification across shore was observed. At the top of the UITZ (as measured 8 m from the neap low tide level up the beach face), was a 20 cm layer of sorted 2 cm pebble. At the bottom of the UITZ (as measured 6 m from the neap low tide level up the beach face), was a well sorted 20 cm layer of small pebble/granule (sample 1A). Below this layer, the subsurface sediments (20 to 40 cm) were similar to the MITZ described next. At the top of the MITZ (as measured 4 m from the neap low tide level up the beach face) and the bottom of the MITZ (as measured 2 m from the neap low tide level up the beach face), the 0 to 20 cm samples contained a higher sand component (see sample 2A and 3A in Table 5). At the neap low tide line, there was a small typical step drop to deeper waters.

4.1.5 Beach #5

Beach #5 which is 5+ km from Sveagruva (see Figure 1), offered several kilometers of usable beach. It has a long west-facing fetch out to the mouth of the fjord (approx. 40 km) and wave energy is relatively high. Typically, it consists of storm berms of 2 to 6 cm shingle, and mixed coarse grain intertidal sediments (pebble, granule, sand), in some places capped by a thin (2 cm) layer of granule.

It was decided that Beach #5 was too remote and would present some logistical problems if it were used as an experimental site. It offered no advantage over Site #4 and was not surveyed further.

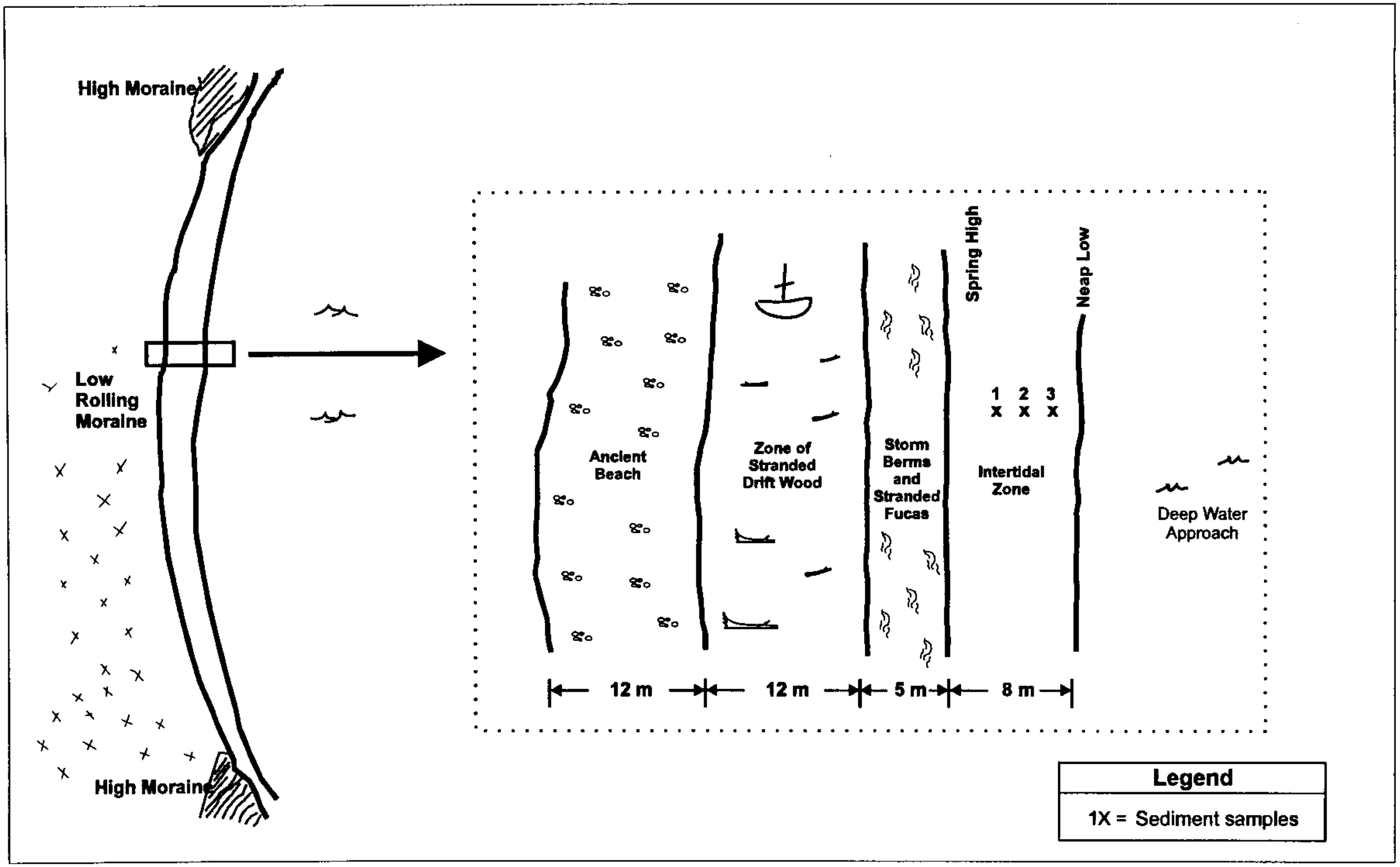


Figure 11. Site #4

4.2 OIL PENETRATION TESTS

The oil penetration tests were carried out near the south end of Beach #2, in a location which was least likely to be used for, or to interfere with, experimental plots. The sediment characteristics at this particular location consisted of a surface clast layer of 2 to 5 cm pebble/shingle and a sub-surface of sandy gravel. The sediments were similar to those of control plot and other usable sections within Beach #2.

Plot sizes of 0.5 m by 0.5 m were used for these tests. The plots were located between the 140 cm and the 70 cm tide lines, the most likely zone to be spanned by the experimental or treatment plots.

All plots were first oiled with the original IF-30 oil, approximately one to two hours before low tide. The wind conditions were calm (0 to 1 m/s) and the temperature was 10°C. Oil loadings of 2.5 and 5.0 L/m^2 were used. A second application of the same oil to the two upper plots was made approximately 13 hours later, just after the next low tide. The wind speed was 5 m/s and temperature 6°C during the second oiling. The plot layout and oil application for each plot are shown below.

140 cm------------------- *high tide line*-----------------------

	U1	**U2**
1st oiling	2.5 L/m^2	5.0 L/m^2
2nd oiling	2.5 L/m^2	2.5 L/m^2
	L1	**L2**
1st oiling	2.5 L/m^2	5.0 L/m^2

70 cm------------------------*low tide line*-------------------------

Key observations were that initial penetration of U1 with 2.5 L/m^2 was only 6 cm, and that 10 cm penetration was attained in both U2 and L2 with 5 L/m^2. Modifications to oil viscosity were therefore not deemed necessary. The second application of oil to U1 and U2 did not increase penetration depth.

4.3 CONTROL PLOT

4.3.1 Site Characterization

The control plot is located towards the south end of Beach #2, as shown in Figure 7. It is similar to other usable sections of Beach #2 (see Section 4.1.2). A single clast layer of 2 to 3 cm diameter pebble was thinly scattered over most of the plot surface. These pebbles were more prolific along the lower edge and below the plot to the water edge. Surface and subsurface sediments consisted of sand /granule /pebble. The results of the grain size analyses of samples collected within the plot are given in Table 6. Below the plot, to the neap low water line, the sediments appeared similar to those in the plot. Below this point, the sediments were mud, similar to the other parts of Beach #2.

Table 6. Grain Size Analysis of the Control Plot

Sample	Depth In cm	Intertidal Location	% Grain Size in mm							
			>31.5mm	>16mm	>8mm	>4mm	>2mm	>1mm	<1mm	Total
CP2-1-1A	0-5	Bloc 1	6.6	14.9	8.1	9.7	26.4	22.3	12.1	100.0
CP2-1-1B	5-10	Bloc 1	6.5	9.6	13.6	19.5	21.2	19.0	10.5	100.0
CP2-1-1C	10-15	Bloc 1	0.0	3.2	11.4	19.4	28.8	25.3	12.0	100.0
CP2-3-1A	0-5	Bloc 3	0.0	8.3	10.7	10.9	29.2	33.1	7.8	100.0
CP2-4-1A	0-5	Bloc 4	7.4	12.2	8.6	16.0	34.1	18.0	3.7	100.0
CP2-4-1B	5-10	Bloc 4	1.9	10.1	7.8	9.4	26.1	30.6	14.1	100.0
CP2-4-1C	10-15	Bloc 4	8.2	12.1	11.3	11.6	22.9	25.0	9.1	100.0
CP1-5-1	0-5	Bloc 5	0.0	12.3	14.4	15.4	16.6	26.3	15.0	100.0
CP2-5-1A	0-5	Bloc 5	3.8	4.0	8.6	12.2	21.8	30.0	19.6	100.0
CP2-5-1B	5-15	Bloc 5	6.8	13.7	11.5	19.3	25.8	12.7	10.2	100.0
CP2-6-1A	0-5	Bloc 6	4.1	9.9	10.0	13.0	28.4	27.2	7.3	100.0
CP2-7-1A	0-5	Bloc 7	0.0	6.4	13.7	12.7	23.2	24.6	19.3	100.0
CP2-8-1A	0-5	Bloc 8	2.9	36.6	14.4	11.5	22.6	9.3	2.6	100.0
CP2-8-1B	5-10	Bloc 8	10.6	20.2	14.2	10.4	18.8	14.9	10.9	100.0
CP2-8-1C	10-15	Bloc 8	1.5	6.7	14.1	13.2	23.1	26.5	14.9	100.0
CP2-9-1A	0-5	Bloc 9	4.4	15.1	17.0	15.1	27.6	17.5	3.3	100.0
CP2-9-1B	5-10	Bloc 9	5.1	12.5	8.9	6.9	17.0	31.6	17.9	100.0
CP2-9-1C	10-15	Bloc 9	0.0	0.0	4.3	10.0	44.5	34.2	7.1	100.0
CP2-10-1A	0-5	Bloc 10	0.2	2.5	2.0	2.7	87.8	2.5	2.1	100.0

Sample Code: e.g. CP2 - 10 - 1A = ContolPlot 2nd sampling period - bloc10 - sample1 depth A where A is 0-5 cm; B is 5-10 cm and C is 10-15 cm.

From grain size analysis of sediments within the control plot,

1) Pebbles constitute
   >30% of the sediments by weight in 7 of the 18 samples,
   >40% in 7 samples, and
   >50% in 4 samples.

2) Sands (<2.0 mm) constitute
   >30% in 11 samples,
   >40% in 7 samples, and
   >50% in 2 samples.

3) Sands (<1.0 mm) occur in all samples but account for:
   >30% in none of the samples.

In general, there is less coarse sediment relative to other surveyed sections of Beach #2. There is a greater proportion of the material in the pebble category <8 mm and in the granule category than on Site #2. There are only 2 of the 25 samples on Site #2 with >25% granules, whereas there are 10 of the 18 >25% on Site #4. The sands are present in approximately the same amounts with an average of 25% in the very coarse sand (VCS) range (1.0 to 2.0 mm) and 10% finer than VCS (< 1 mm) on Site #4. The similar numbers for Site #2 are 17% of VCS and 20% for finer than VCS, indicating less VCS but more finer than VCS on Site #2.

The slope of the control plot is on the order of 13 degrees, and is lower than other usable sections of Beach #2. The north side of the plot (bloc 10) had an even flatter slope and sediments were obviously more water saturated.

Littoral drift was documented at several locations along Beach #2 and within the control plot. The predominant direction of littoral drift was alongshore towards Sveagruva, although drift in both directions was observed. As expected, the littoral drift was dependant on wind direction and sea state. Littoral drift of the surface pebble clast layer averaged about 10 m.

An unusual summer storm event occurred the night of August 5. Such an event is not common in this region during summer months. Winds of 13 m/s were measured at the airport, and these would have been considerably higher on the exposed beach. The high wind and waves were almost directly on-shore, and were a statistically rare event.

4.3.2 Set-up and Oiling

The control plot measured 5 m by 23 m long (total oiled area). The upper edge of the plot was at the 150 cm high water mark above the neap high tide line. The entire plot was flooded within a few hours of oiling and for 5 additional high tides before the first sampling period. The distance from the bottom of the plot to the neap low water line was about 10 m.

A total of 560 L of oil was applied to the control plot on August 2, 1996 at low tide under very calm conditions. The wind speed was less than 1 m/s and there was almost no wave action. The sky was overcast and air temperature was 5°C. The oil loading over this area was 4.9 L per square meter. Oil was applied relatively slowly due to limitations of the discharge system. The effective sampling area was 4 m by 20 m. A sketch of the plot and sub-division (blocs) is given in Figure 4.

4.3.3 Oil Behaviour and Distribution

During the oiling phase, penetration was relatively rapid, and no oil runoff was observed except in Bloc 10 where excessive amounts of oil ran down slope. Penetration was being blocked by the water-saturated sediments in this 'low' area within the plot.

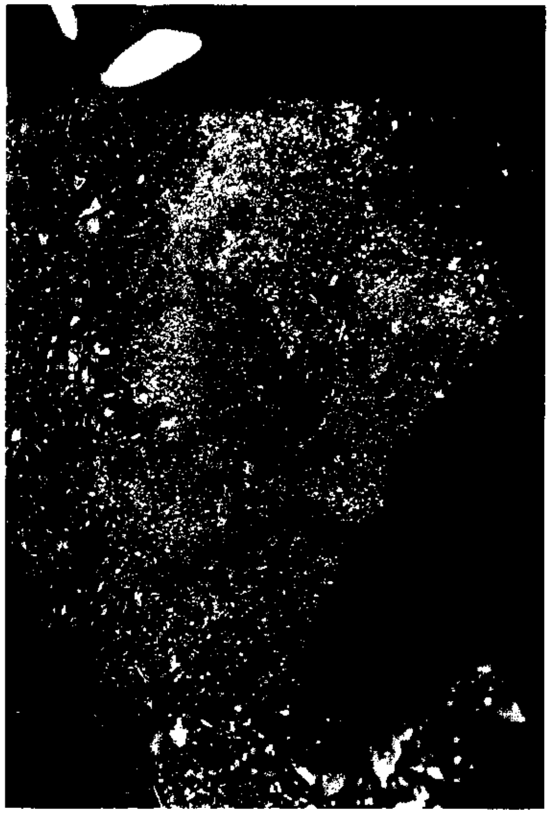
During the rising tide, winds were at 5 to 7 m/s with very small ripple-sized waves (<5 cm). During the flood period and within a few hours thereafter, there was a noticeable loss of oil from the surface pebble clast layer. Oil cover on the pebble decreased from 100% to about 30%. Sheen and large drops of oil were observed surfacing from the sediments themselves but the total oil loss was relatively minor.

The oil in the beach sediments was judged to be relative stable within 48 hours of oiling by which time no black oil and only sheen was being refloated and released from the sediments. Total oil loss from the beach to within the boomed area was not sufficient to use the skimmer. Instead, oil which had herded along the boom edge was 'sucked' into barrels using a small gear pump and hose.

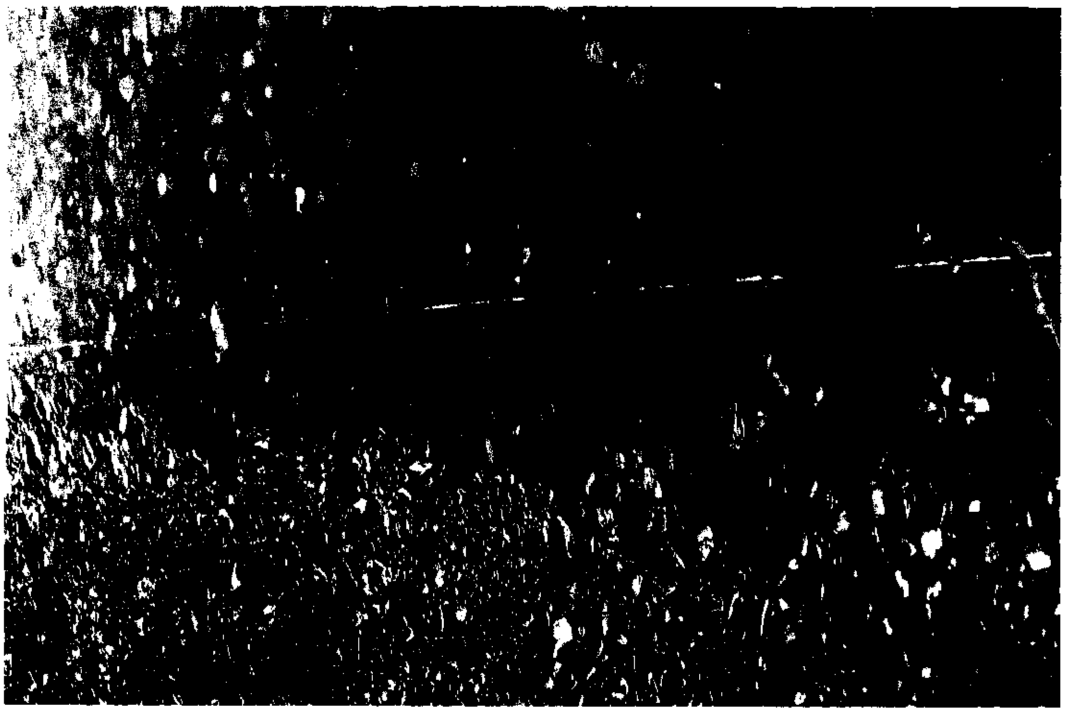
By 48 hours, there was significant off-plot movement of oil (see Figure 12) to adjacent surface sediments. An 1 to 1.5 m band of oil was stranded at the high tide line above the plot. This high tide strand line remained for the next two weeks. Alongshore, oil was moved northward about 3 m. This movement reached a

Plate 6

Collection of Sediment Sample in Control Plot 05/08/96



Pit in Oiled Control Plot 05/08/96:
Note Surface Oil and Subsurface Oil Pockets



Lower Edge of Control Plot on First Rising Tide distance of about 20 m by 72 hours post-spill. During this period, the harbour boom was not effective in containing the oil at the intertidal interface. In addition, during the period of storm activity or high wave conditions, the boom was causing a groyne effect at the point where it contacted the intertidal zone. Natural sediment redistribution was being altered.

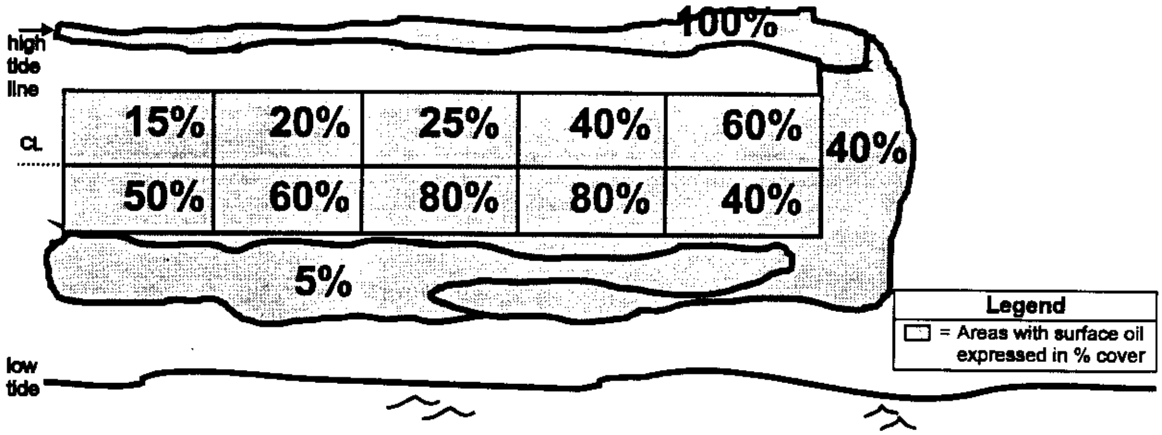


Figure 12. Surface Oil Movement "Off-Plot"

On the night of August 5, unusual storm activity caused a burial of the plot and patches of oil had been moved off-plot about 100 m to the north. This was considered to be a very atypical event. Only very light sheening (from a silvery to rainbow colours) was observed from the control plot at the time of the last sample, 15 days after oiling (August 14, 1996). This sheen corresponded to a thickness of approximately 0.08-0.3 μm (Fingas et al., 1979). This sheening posed no threat or cause for concern and no remedial or response action was recommended.

Oil cover observations are presented in Table 7. Generally the overall oil cover on the plot remained relatively constant for the first 72 hours. There were changes within the plot but the overall average did not alter significantly, except on the night of August 5 when an unusual storm buried the plot. In the days following, surface oil increased as some of that material was naturally removed (unburied). Two observers were used to record oil cover. Agreement between the two observers was very high. This, despite the fact that the observers had not been cross-calibrated and one observer was new and untrained. Recorded oil distribution during the first two periods (dull overcast) was close. Larger differences are evident on the August 5 observations, a sunny day.

Table 7. Oil Cover Observations

Survey	Date	% Oil Cover on Each Bloc										Plot	Distribution
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Avg	Category
A	03.08.96	20	80	35	90	35	75	45	85	60	55	58	broken
B	03.08.96	15	70	20	70	20	80	50	80	60	50	52	broken
A	04.08.96	10	50	30	70	35	80	40	80	40	50	49	patchy
B	04.08.96	15	50	20	60	25	80	40	80	60	40	47	patchy
A	05.08.96	70	70	60	50	80	60	80	70	95	80	72	broken
B	05.08.96	65	40	55	30	60	35	75	40	90	35	53	broken
A/B	06.08.96	5	5	5	5	5	5	5	5	5	5	5	sporatic
A	14.08.96	12	10	15	6	20	15	30	20	20	15	16	patchy
B	14.08.96	15	6	15	5	20	8	20	10	15	10	12	patchy
A	16.08.96	10	15		30		30		40		40	24	patchy

Penetration of oil into sediments was initially rapid except in the waterlogged sediments of Bloc 10. Immediately after oiling, observation of several pits around the outside edges of the plot indicated oil up to the 10 cm depth and of the 'partially filled pore' category (Owens & Sergy, 1994). Further observations were taken 24 hours post-spill along T0, T3 and T5 and 48 hours post-spill along the plot centerline (CL), and then within each bloc at the time of sediment sampling (see Table 8).

Table 8. Oil Penetration Observations

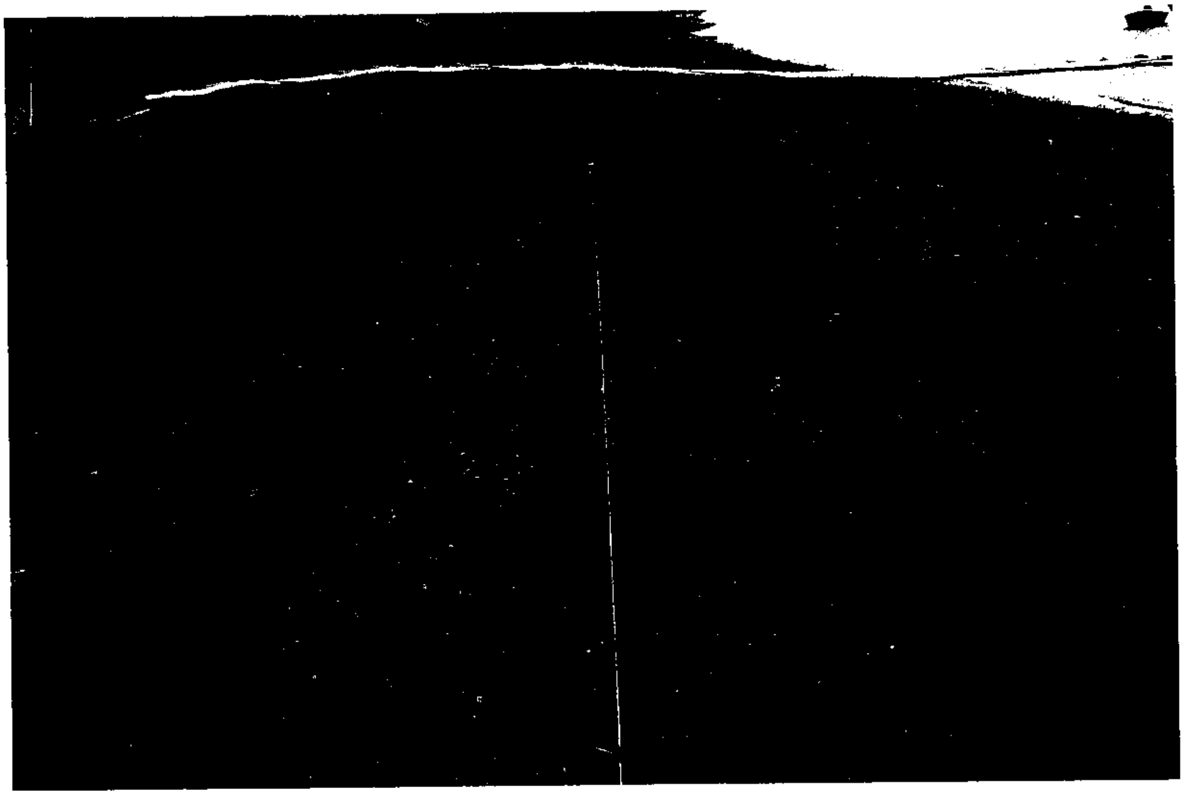
Date	Penetration Depth in cm within each Bloc									
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
03.08.96	8	6			8	6			7	5
05.08.96	10		15	5	5	10	8	10	11	5
14.08.96*	19	20	20	12	11	8	5	6	20	10
	Penetration Depth (in cm) every 2 m along Centerline*									
	0	2	4	6	8	10	12	14	16	18
04.08.96	5	10	9	7.5	7	6	7	7	10	10

**(from B1/2 > B9/10)*

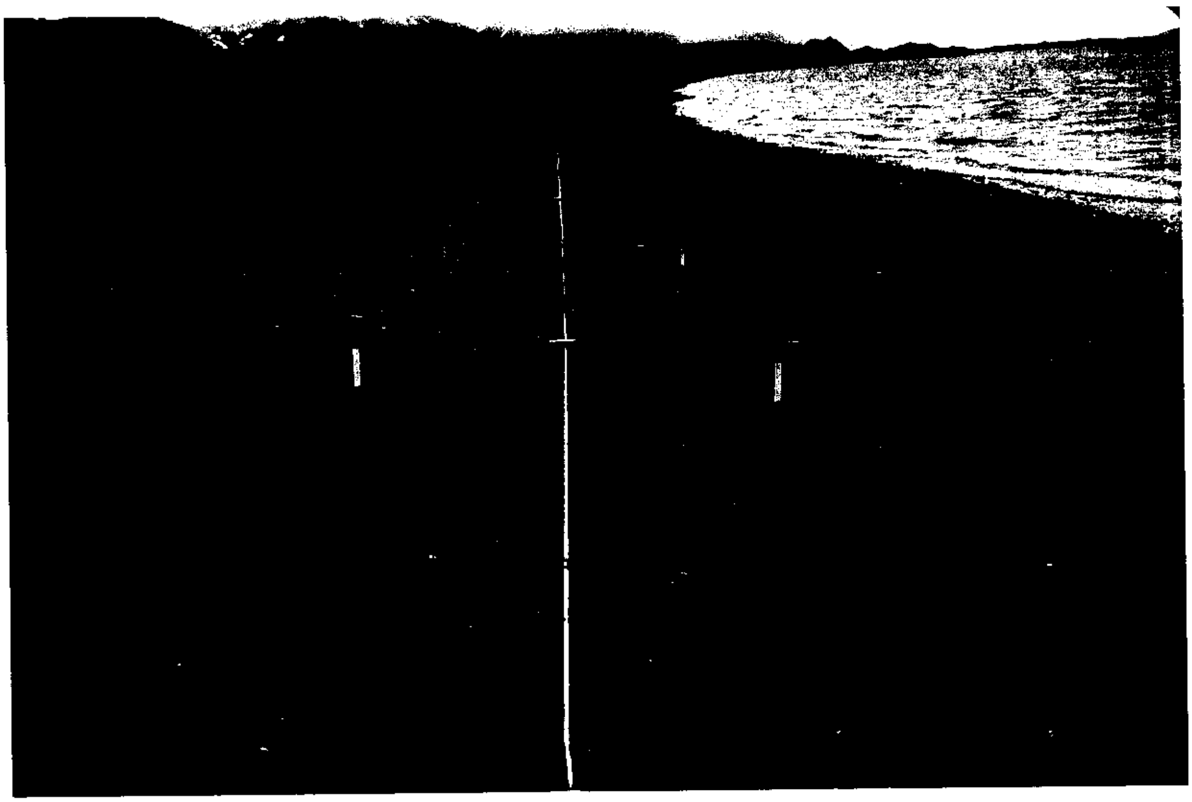
Generally speaking, penetration was difficult to assess due to the general grey color and wetness of sediments and the consistantly overcast conditions. The most important observations were that:

- initial penetration of 10 cm was achieved,
- penetration was not of equal depth across the plot, and
- subsurface oil distribution was not even.

Plate 7

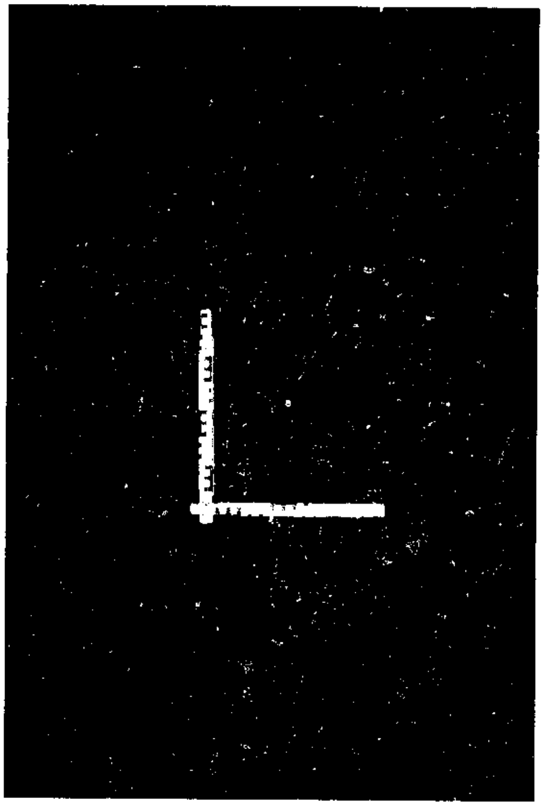


Oblique of Control Plot: 1 Day Post Oiling

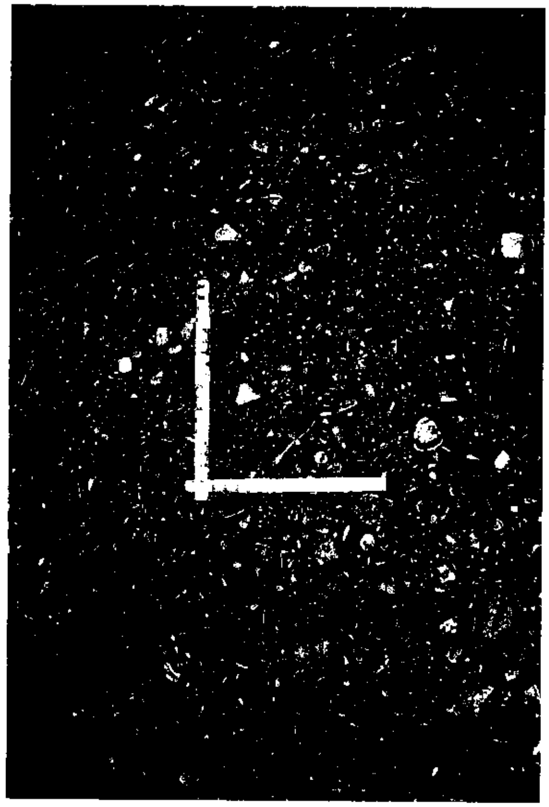


Oblique of Control Plot: 12 Day Post Oiling

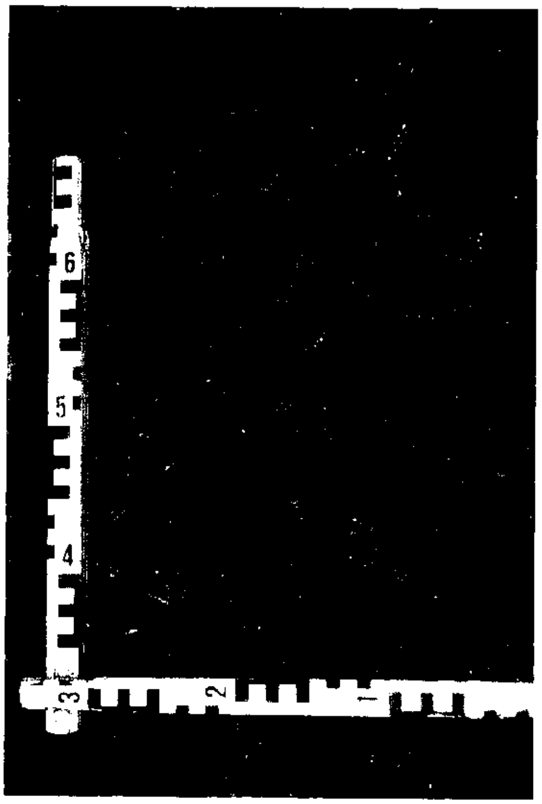
Plate 8



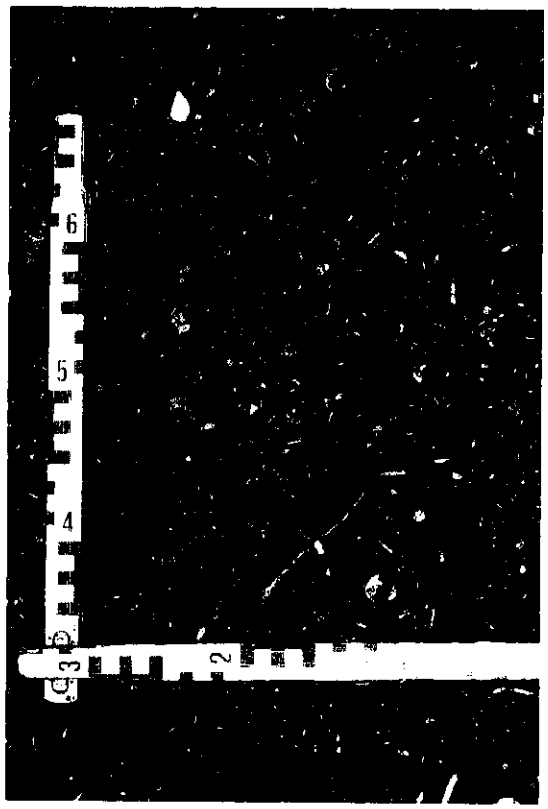
Vertical Closeup of Control Pot: 1 Day Post Oiling



Vertical Closeup of Control Plot: 12 Day Post Oiling



Vertical Closeup of Control Plot: 1 Day Post Oiling



Vertical Closeup of Control Plot: 12 Day Post Oiling

Subsurface oil deposits were sometimes continuous from surface to oiling depth, or else in the form of lenses and pockets. It is not clear whether the irregular distribution patterns found after several days are a result of oil relocation or removal patterns, or of oil penetration and depositional patterns. In any event these changes likely were caused by a combination of factors such as tidal water movement, differences in sediment size distribution, compaction, sediment deposition, and sediment wetness. These observations are not supprising but do lead to several recommendations and refinements concerning oiling for 1997 as discussed in Section 6.

4.3.4 TPH Analysis

Sediment samples were collected for Total Petroleum Hydrocarbon (TPH) analysis, on day 3 and day 12 after the oiling. These were collected systematically at pre-determined locations within each bloc as measured from the centerline of the plot (i.e., there was a fixed systematic coverage of the plot rather than a random sample pattern). Sample collection logs are provided in Appendix I.

Both gravimetrically-determined TSEM and GC-determined TPH were obtained from each sample.

TSEM stands for the total solvent extractable materials. TSEM values were determined gravimetrically. An aliquot of the extract (10 mL) was blown down with nitrogen to a residue and weighed on a microbalance to obtain the TSEM (expressed in mg/g of sample).

The GC-TPH or total gas chromatograph (GC) detectable petroleum hydrocarbons are defined as the sum of all GC-resolved and unresolved hydrocarbons. The resolvable hydrocarbons appear as peaks and the unresolvable hydrocarbons appear as the area between the lower baseline and the curve defining the base of the resolvable peaks. In general, the GC-TPH values are smaller than TSEM values. This result occurs because a portion of high molecular weight hydrocarbons stay on the column and would not be detected by GC detector.

Laboratory data for TSEM and GC-TPH are presented in Appendix II. The concentration data is summarized in Table 9 and discussed below with respect to experimental design.

Table 9. Summary of Control Plot Oil in Sediment Concentrations

Intertidal Location	Depth (cm)	Grav. TSEM mg TSEM/g sed	GC-TPH mg/g sed
1 Day Post Oiling			
Bloc 5	0-5	27.39	18.24
3 Days Post Oiling			
Bloc 1	0-5	8.12	5.15
Bloc 1	5-10	17.57	11.11
Bloc 1	10-15	0.75	0.51
Bloc 2	0-5	9.16	6.46
Bloc 3	0-5	8.53	5.67
Bloc 4	0-5	21.85	14.55
Bloc 4	5-10	21.63	15.01
Bloc 4	10-15	1.18	0.80
Bloc 5	0-5	14.58	9.70
Bloc 5	5-15	0.51	0.35
Bloc 6	0-5	6.63	4.61
Bloc 7	0-5	15.30	10.50
Bloc 8	0-5	9.13	6.20
Bloc 8	5-10	15.93	10.82
Bloc 8	10-15	0.78	0.53
Bloc 9	0-5	15.05	10.32
Bloc 9	5-10	14.22	9.70
Bloc 9	10-15	0.34	0.19
Bloc 10	0-5	2.33	1.62
12 Days Post Oiling			
Bloc 1	0-5	0.93	0.61
Bloc 1	5-10	0.25	0.17
Bloc 2	0-5	0.49	0.34
Bloc 3	0-5	6.25	3.87
Bloc 3	5-?	8.98	5.85
Bloc 4	0-5	0.24	0.16
Bloc 5	0-5	0.24	0.16
Bloc 5	5-10	0.03	0.02
Bloc 6	0-5	0.15	0.09
Bloc 7	0-5	0.07	0.05
Bloc 7	5-15	0.03	0.02
Bloc 8	0-5	0.36	0.23
Bloc 9	0-5	10.81	6.73
Bloc 9	5-10	16.55	10.93
Bloc 10	0-5	0.58	0.38

TSEM vs. TPH

As part of the analytical protocol, the gravimetric TSEM is determined prior to a gas chromatographic analysis for TPH. For environmental samples, the latter analysis is often necessary to distinguish natural hydrocarbons from petroleum hydrocarbons, especially at low hydrocarbon concentrations.

For the samples in this study, the TPH analysis is probably not necessary unless compositional changes may be expected (if the oiled sediment is sampled after a long period of time exposed to weathering, for example). When high concentrations of hydrocarbon are exposed for short periods of time, few compositional changes are expected. To test the consistency of the two analyses, the ratio of TPH to TSEM was examined. The ratio proved to be very consistent, with the exception of sample CP2-9-1C. The TPH method can be considered to determine a sub-set of the compounds determined by the TSEM method, and does not contribute to our understanding of the oil removal process at this time.

TSEM differences

The TSEM data were examined according to tidal level, time (by whole plot) and sediment depth. As well, temporal differences were determined for individual blocks when there were data for the same block on more than one occasion.

Tide level: An analysis of variance (ANOVA) indicated that there were no differences for any sediment depths at any time for even blocks (lower tidal zone) compared to odd blocks (upper tidal zone). This implies that the plots are narrow enough to be in a consistent tide regime.

Surface vs. subsurface: An ANOVA indicated that there were no significant differences between surface (0 to 5 cm) and subsurface (5 to 10 cm) samples at the same time. In part, this lack of difference may be due to the small number of subsurface samples analyzed (see below).

Temporal changes: Some blocks were sampled on two occasions. The oil loss recorded for these blocks are shown in Table 10. Note that the oil losses range from ~25% to ~100%, with one exception, when more oil was found during the second sampling.

Table 10. Loss of Oil Between Day 3 and Day 12 Samples from the Same Block

Sample	Location	Depth	% Change
1-1A	Bloc 1	0-5 cm	89%
2-1A	Bloc 2	0-5 cm	95%
3-1A	Bloc 3	0-5 cm	27%
4-1A	Bloc 4	0-5 cm	99%
5-1A	Bloc 5	0-5 cm	98%
6-1A	Bloc 6	0-5 cm	98%
7-1A	Bloc 7	0-5 cm	100%
8-1A	Bloc 8	0-5 cm	96%
9-1A	Bloc 9	0-5 cm	28%
10-1A	Bloc 10	0-5 cm	75%
1-1B	Bloc 1	5-10 cm	99%
5-1B	Bloc 5	5-10 cm	93%
9-1B	Bloc 9	5-10 cm	-16%

An ANOVA was done on all data to determine if significant changes occurred between sampling periods at the same sediment depths. For surface samples (0 to 5 cm), a difference was found at >99% significance. For subsurface samples, a difference was found at ~95% significance. For the deep samples, there was no significant difference between sampling periods. This was probably due to the small number of deep samples analyzed. ANOVA for all sediment depths combined indicated a difference between sampling periods at better than 99.9% significance.

Sample size

There was considerable variation in sample size, and it would be cost-effective to reduce the average sample size if there is no observed effect of sample size on outcome. A plot of TPH, TSEM and the TPH/TSEM ratio indicates that there is no apparent bias based on sample size (Figure 13). Note the sample with the very low weight, sample CP2-9-1C, which again appears to be different from the main set of samples. CP2-9-1C is a small sample of predominantly fine sediment, taken from deep within the beach. It is likely that this sample represents the top of the fine sediment layer under the pebble-granule armour layer, and as such, should not be sampled.

The TPH/TSEM ratios are quite constant (between ~600 mg TPH/g TSEM and ~700 mg TPH/g TSEM independent of sample weight), while both TPH and TSEM do not appear to correlate with sample weight. It is probable that samples of about 2 kg would be as suitable as samples of up to 5 kg.

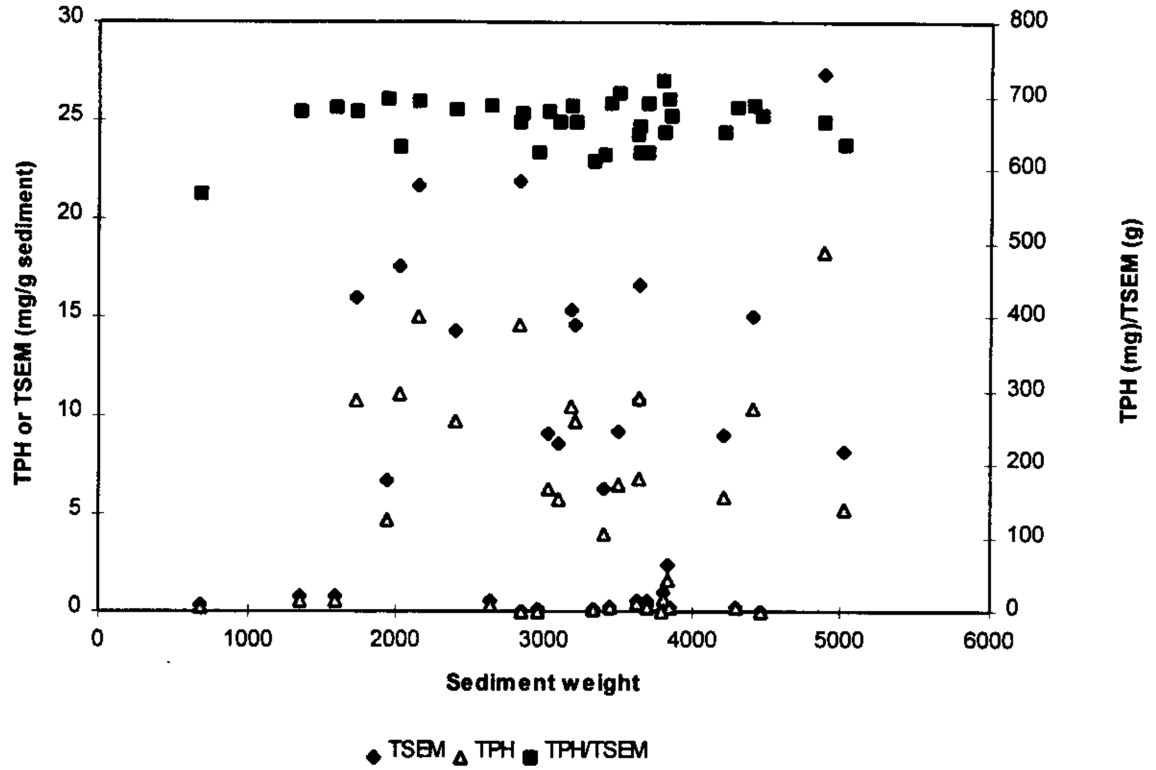


Figure 13. TSEM and TPH vs. Sediment Weight

Sample number

The data for each time and sediment depth were examined to determine an optimal sample number per plot/time. Each sample is costly to collect and analyse, and one wishes to minimize this cost while obtaining an appropriately precise outcome. Using the data from 1996, it is possible to determine the number of samples needed to determine the concentration of oil on each plot/time with any selected precision. For this analysis, the standard deviations of the plot/time/sediment depth combinations were examined. The set with the highest standard deviation was the August 14 subsurface set. Based on that set, the expected precision for future sampling is shown in Table 11. The 1996 data indicated average changes of ~80%, on initial concentrations of ~15 mg oil/g sediment. A precision of 5 mg/g would be more than adequate to see the expected changes of 12 mg/g. If more complete removal of oil is expected for some treatments, then 5 samples per plot/time/sediment depth will be adequate, assuming an average initial loading of 15 mg/g (1.5%; 15,000 ppm). A similar analysis based on the standard deviation of results from all data (surface and subsurface) for each phase results in slightly lower sample numbers required.

Table 11. Sample Numbers vs. Precision

Desired precision (mg oil/g sediment)	Minimum # Samples (based on worst sediment dependent example)	Minimum # Samples (based on sediment depth independent analysis)
7.5	5	2
5	10	6
4	15	8
3	30	14
2	60	30
1	240	120

4.4 WILDLIFE OBSERVATIONS

A record of all wildlife observed during the experimental period was kept. A number of species were observed in the area, on land and in the water. These included various birds; ducks, seals, walruses, whales, arctic foxes and polar bears. Animals spotted in the water were at least 50 m from shore. Polar bear tracks were spotted in the moraines behind the beach, and on one occasion, a polar bear broke into the wooden cabin at the test site. Polar bears had been a particular nuisance during the summer in the Sveagruva area, breaking into a number of cabins and spotted at the dump on a number of occasions.

After oiling the control plot, personnel were on site at regular intervals to discourage visitors to the site. There was never any sign or sighting of wildlife on or in the immediate area surrounding the control plot. Wildlife occurrences in the immediate vicinity of Beach #2 are minimised due to the regular traffic between Sveagruva and Kapp Amsterdam related to the mining activities.

5.0 DISCUSSION

Potential beaches were surveyed as planned, however, the predominance of intertidal clay sediments was not expected. Both the occurrence of surface patches or lumps of clay and of a clay foundation overlain with too shallow deposits of coarse sediments, eliminated large segments of intertidal beach as being suitable. This is particularly the situation in Beaches #1 and #2. Despite the elimination of large portions of the beach as being unsuitable, several segments were found to meet the selection criteria.

In an overall rating of all candidate beaches, the Site #2 >1 >4 >3 >5.

- Site #2 provides a medium energy beach with 140 m of continuous suitable or usable MITZ/UITZ and a 40 m adjacent section. This site could support 4 plots of 35 to 40 m each (e.g., 3 treatments and a control). Site #2 provides relatively easy land access.
- Site #1 provides a shorter and lower energy section of about 70 to 80 m which could support 2 plots of 35 m each. Site #1 is difficult to reach by sea due to the mud flats and can only be reached by land at low tide, unless permits allowed overland travel.
- Site #4 has the most extensive suitable area but is a relatively higher wave-energy environment. It would be suitable only for testing very short-term techniques, such as surf washing or berm relocation. Boat access is relatively easy due to the deep near shore water.

Generally, the grain size distribution of all beaches and the control plot was similar for most samples from all tidal zones (graphical depiction in Appendix III). The sediments at the three best sites (#1, 2 and 4) are relatively comparable, being a mixed population of pebbles, granules and sands. Sites #1 and #4 have less sands finer than VCS, but also have less material at the coarse end of the pebble range, indicating that they are better sorted with a dominant fine pebble-granule-VCS character. However, Site #1 has angular pebbles, indicating that this is a low wave-energy environment. By contrast, Site #4 is clearly more exposed and has well-sorted sediments and a well-defined beach step at the base of the beach-face slope. No obvious alongshore, across-shore, or depth trends can be defined from the sediment analayis data.

The selected oil (IF-30) appears to be acceptable without adjustment. The minimum 10 cm penetration could be attained in sediments which were of equal or greater wetness than those being proposed for full scale trials. Oil retention of up to 150,000 ppm (1.5%) by weight was found in some of the sediments after 12 days. This retention is considered to be in the range of oiling suitable for in-situ cleanup techniques. However, average oil loading for the plot at day 3 and 12 was less than hoped for. The changes in oiling in 1996 were due to natural forces, including sediment mobilization and tidal flushing. For the operational experiments in 1997, any changes due to applied treatments will be confused with natural removal if the latter is too large. For the 1996 plots, 9 days were enough to remove between 25% and 100% of the spilled oil. Steps to retard removal or enhance retention are suggested below. It should also be noted that the expression 'remove' must be considered operationally. For the 1996 experiment, oil was removed if the measured oil at each sediment depth decreased. Another explanation for this removal could be that the oil was moved away from the precise sampling locations. This is apparent in the samples from Block 9. Although 28% of the oil was removed from the surface, at least some of it ended up in the subsurface.

For 1997, It is expected that oil retention can be increased in several ways. First, the proposed sites are all of equal or greater porosity and dryness than the control plot. Second, oil was applied on a relatively cold day. If oil were to be applied during warmer conditions, then penetration would be increased as viscosity is very temperature dependent. Thirdly, the 1996 control plot straddled the neap high water line, i.e. part was in the MITZ and part in the UITZ. The lower portions were visibly poorly drained and the water table only 15 cm deep at the bottom of the plot at low tide. If the 1997 trials are conducted higher up the beach face in the UITZ, then greater penetration and retention could be expected, since these sediments are better drained than those in the MITZ, i.e., a higher oil loading also could be expected. As a priority zone of the beach, the UITZ is that area which tends to receive and retain most of the oil.

In evaluation of the oiling system, we concluded that it was satisfactory for the control plot but impractical for oiling a larger area or number of plots within the same tide window. For the area that is anticipated to be oiled in 1997, both larger pumps and a longer discharge pipe will be required. The main adaptation is to increase the length of pipe to equal the width of the test plot so it can be entirely oiled in a single pass. The pump should be capable of providing pressure in excess of that required for the target flow rate, so it can be increased if conditions allow it. Extensions handles on the discharge pipe will allow those holding it to remain outside the oiled area, as some oil pooling in footprints was observed in the 1996 trials.

With respect to boom configuration around the plot, we feel that it proved adequate to contain oil on the water but leakage occurred at the intertidal interface. The use of multiple rows of sorbant boom and intertidal boom is suggested for 1997. A second problem encountered was anchoring the booms too close to the edge of the plot, which interfered with natural sediment transport process. At 10 m buffer is suggested.

The bulk sediment extraction protocol proved suitable, with the modifications put in place in the Sveagruva lab, but was relatively time consuming and not efficient for the large number of samples anticipated for 1997. The equipment used in the protocol will need to be re-selected and modified for increased effectiveness for the 1997 trials.

6.0 DESIGN RECOMMENDATIONS FOR THE 1997 TRIALS

Based on the findings from the 1996 trials, the following detailing and modification of the existing April 1996 experimental design can be recommended for the 1997 trials.

Experimental sites and treatments
Suitable sites for the 1997 field trials are located on Beaches 1, 2 and 4.
Beach #2 would be used for a tilling, bioremediation, tilling combined with bioremediation, and a control plot. This beach has the longest stretch of suitable intertidal sediment and will therefore permit all plots to be located on similar sediments with similar exposure. This reduces the number of control plots required and will allow for easier comparison between each treatment technique.

Beach #1 is recommended for surf washing (sediment relocation) in a low energy setting. As one of the aims of this research programme is to study the acceleration of OFI, it is of interest to test surf washing, a technique usually used on high energy beaches, as a method of enhancing OFI as opposed to mechanical abrasion.

It would also be desirable to carry out surf washing on Beach #4, a high energy beach. Previous cleanup operations have demonstrated that surf washing can be an effective technique, but quantitative data has not been collected during these spill events. A surf washing study on Beach #4 would provide relevant data to support this technique.

Discharge system design
The discharge system will be similar to that used in the 1996 field trials but with a higher discharge capacity. Oil will be pumped through a perforated pipe which will be long enough to span the entire cross shore width of the plot (i.e., 3 to 4 m). This will increase the rate at which the plots can be oiled, and will avoid the need to step over oiled areas of the plot as the oil is being applied.

Oil type and loading
The oil type used in the field trial will be IF-30, the same oil used in the 1996 field trial and the basin experiments in Trondheim and Texas. An estimated oil loading of $5 L/m^2$ will be used, however the final loading will be based on the results from the basin experiments.

Size, Width and Location of plots in the intertidal zone

The top of each plot will be located at or just below the spring high water mark (approximately 175 cm) and will include all of the UITZ. As a priority zone of the beach, the UITZ is that area which tends to receive and retain most of the oil. Depending on the treatment, plot sizes of 30 - 40 m alongshore length and 3 - 4 m cross shore width will be used. This width will thus also capture the upper half of the MITZ.

Time of oiling and treatments with respect to the tidal cycle

Timing for oiling and treating the plots will be coordinated with specific phases of the monthly cycle of spring and neap tides. The strategy will be to allow the maximum time for the oil to penetrate and adhere into the sediment before natural tidal flushing and application of treatment techniques.

All test plots will be oiled during the daily low tide of the neap tide phase. The most likely window is from July 28 to Jul 31, 1997. Daily tide height begins to increase by August 1, as it shifts to the spring tide phase, which peaks on August 05 and 6. Thus that portion of the plot in the UITZ will not experience total tidal flooding until about a week after oiling has occurred.

The tilling treatment will be carried out during the peak of the spring tide phase, which is approximately 8 to 10 days after oiling. It will done during the low tide of the day (the spring low tide). At this point, the plots will have been covered entirely in water for one or more tides, and subsequent (post-treatment) tidal exposure will continue to wash the plots. An optional add-on variation for tilling is to oil an adjacent plot (at the same time as the others), and then till it after 48 - 72 hours. This would add useful data on two more scenarios, i.e. tilling shortly after oiling in the MITZ and tilling before natural flushing in the UITZ.

Two similar strategies are proposed for the surf washing (sediment relocation) trials in terms of timing of the treatment. The first is to treat part of the plot (or a separate plot) about 72 hours after oiling, before the spring tide peak and thus before the plot has been flooded and washed. The second strategy is to treat part of the plot (or another plot) about 8 days after oiling, after it has been flushed a few times by the spring high tides. This will provide data on two different oil loadings and scenario's for oil stranded in the UITZ.

The additional options for tilling and surf washing will add some additional effort for treatment and several additional sets of samples. However, since the infrastructure is in place, the cost-benefit is favourable and the additional cost is marginal in comparison to getting data sets on different scenarios.

Sample size
A sample size of about 2 kg - 3kg or about 1.5 L will be used. This is of sufficient size to overcome sediment heterogeneity.

Surface sediment movement
Fixed benchmark pins will be positioned at the corner of each (4 x 5 m) bloc and the original surface level (S_o) marked on the pin. Sediment deposition and erosion in relation to the original surface at time of oiling (S_o), will be recorded for each bloc at every sampling.

Sample Number and Depth
It must be recounted that with respect to evaluation of oil removal by natural processes and the performance of the treatments, <u>the prime objective is to have a quantitative representation of the total amount of oil</u> within each single plot. Knowledge of the variation and changes within the plot, though interesting, are not essential as long as the sampling scheme and results represent the total plot. The basic strategy is to chase, sample and determine changes in the 'oil-sediment' mass.

A systematic sample scheme will be used on the plots (as per 1996) taking 1 sample per bloc per sample period. Based on analysis of 1996 data, an estimated 10 samples per 4 x 20 m plot is deemed adequate. In the case of surf washing where the sediments on the oiled plot have been moved, then the sampling grid for the relocated sediment berms will be contoured to the shape and redistribution of the berms.

Intertidal surface and subsurface will not be separated or sub-sampled. A single sample will be composed of a vertical composite of sediment from the surface to a fixed depth. The exact depth for each plot could be unique and will be determined as follows:

(a) In the absence of obtrusive treatment, depth will be defined immediately after oiling by determining an average depth of penetration (D_p) prior to the first flood tide. It will remain at the same plane thereafter, even though the actual surface of the plot will vary with sediment erosion and deposition. A composite sample will include sediment from the surface (where ever it is at time of sampling) to the original depth (D_p) set at time of oiling.

(b) In the case of the tilling treatment, sample depth will be either,
(I) the original depth of penetration (D_p) or
(ii) if tilling depth (D_t) exceeds D_p, then the sample depth is (D_t)
In practice, it is desirable that (D_p) = (D_t)

(c) In the case of the sediment relocation (surf washing) plots, sample depth in relocated oiled sediments will be from the existing surface of the oiled relocated sediment to the original beach face (S_o). However, a second zone of sampling will also be established below the original beach face plane to a depth of 10 cm or greater if oil is observed.

The surface clast layer of scattered pebbles is quite mobile and, as is typically the rule, will be ignored in vertical profiling. The surface, or depth 0 cm, does not include these pebbles.

Bulk sediment extraction protocol.
The basic technique used in 1996 will be used in 1997 with modifications in equipment to improve efficiency. These will be tested in the beach basin trials in Texas and Trondheim.

Chemical Analytical Technical
Total oil will be determined by gravimetric total solvent extractable material (TSEM). Samples will be archived for potential future GC-TPH or GCMS

7.0 REFERENCES

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APPENDIX I. Laboratory Log of Sediment Extractions (Page 1)

TASK	Sample ID # CP1-5-1A	Sample ID # CP2-1-1A*	Sample ID # CP2-1-1B*	Sample ID # CP2-1-1C	Sample ID # CP2-2-1A*
Processing Date:	11.08.96	11.08.96	16.08.96	16.08.96	16.08.96
Weight Oiled Sediment (g)	4888.8	5027.9	2030.2	1359.8	3505.0
Container (g)	575.8	25.4	577.6	582.0	576.2
Cont.+Oiled Sediment (g)	5464.6	5053.3	2607.8	1941.8	4081.2
Vol Rinse #1 (mL)	200	200	200	200	200
Vol Rinse #2 (mL)	200	200	200	200	150
Vol Rinse #3 (mL)	150	200	150		150
Vol Rinse #X (mL)	100,100	150	150,150		150
Shake Time per Rinse (min)	5	5	5	5	5
Weight Erlenmeyer (g)	310.773	300.820	366.593	291.917	215.528
Erlenmeyer + Extract (g)	1221.500	1044.108	1419.583	696.900	800.532
Extract (g) calc.	910.727	743.288	1052.990	404.983	585.004
Vial 1 + label (g)	15.034	15.069	14.863	15.020	14.942
Vial 2 + label (g)	15.007	15.008	14.939	14.936	15.035
Vial 3 + label (g)	14.907	14.908	14.935	14.851	14.897
Vial 4 + label (g)	14.795	14.928	14.996	14.936	15.048
Vial 1 + lid (g)	16.596	16.564	16.472	16.546	16.543
Vial 2 + lid (g)	16.700	16.531	16.524	16.474	16.606
Vial 3 + lid (g)	16.494	16.437	16.535	16.326	16.419
Vial 4 + lid (g)	16.462	16.458	16.564	16.447	16.545
Vial 1 +lid +extract (g)	39.210	40.888	42.443	42.989	42.161
Vial 2 +lid +extract (g)	40.418	42.093	42.832	42.331	42.019
Vial 3 +lid +extract (g)	39.667	41.972	42.553	42.666	41.363
Vial 4 +lid +extract (g)	39.964	42.318	42.765	41.977	41.770
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 2)

TASK	Sample ID # CP2-3-1A*	Sample ID # CP2-4-1A*	Sample ID # CP2-4-1B*	Sample ID # CP2-4-1C*	Sample ID # CP2-5-1A*
Processing Date:	16.08.96	16.08.96	16.08.96	11.08.96	16.08.96
Weight Oiled Sediment (g)	3096.1	2831.7	2143.7	2841.7	3208.8
Container (g)	578.9	583.1	580.3	24.8	581.4
Cont.+Oiled Sediment (g)	3675.0	3414.8	2724.0	2866.5	3790.2
Vol Rinse #1 (mL)	200	200	200	200	200
Vol Rinse #2 (mL)	150	200	200	200	200
Vol Rinse #3 (mL)	150	200	150	0	200
Vol Rinse #X (mL)	150	150	150	0	150+150
Shake Time per Rinse (min)	5	5	5 *	5	5 *
Weight Erlenmeyer (g)	299.994	291.939	330.470	291.818	351.381
Erlenmeyer + Extract (g)	1174.970	1101.975	1363.450	643.083	1331.603
Extract (g) calc.	874.976	810.036	1032.980	351.265	980.222
Vial 1 + label (g)	14.952	14.900	14.929	14.972	15.020
Vial 2 + label (g)	15.078	14.997	14.907	14.904	15.006
Vial 3 + label (g)	14.938	14.917	15.043	14.949	14.877
Vial 4 + label (g)	14.967	14.903	15.006	14.874	14.930
Vial 1 + lid (g)	16.473	16.461	16.448	16.495	16.534
Vial 2 + lid (g)	16.578	16.527	16.429	16.372	16.525
Vial 3 + lid (g)	16.455	16.453	16.559	16.501	16.409
Vial 4 + lid (g)	16.493	16.441	16.522	16.383	16.466
Vial 1 +lid +extract (g)	42.034	41.404	42.695	42.068	42.024
Vial 2 +lid +extract (g)	42.614	41.682	41.818	42.368	42.538
Vial 3 +lid +extract (g)	41.979	41.679	42.169	42.379	41.594
Vial 4 +lid +extract (g)	42.982	41.531	42.485	42.054	41.656
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 3)

TASK	Sample ID # CP2-5-1B*	Sample ID # CP2-6-1A*	Sample ID # CP2-7-1A	Sample ID # CP2-8-1A	Sample ID # CP2-8-1B
Processing Date:	11.08.96	16.08.96	17.08.96	17.08.96	17.08.96
Weight Oiled Sediment (g)	2632.7	1943.9	3178.5	3021.7	1735.8
Container (g)	18.8	581.9	584.5	583.4	580.4
Cont.+Oiled Sediment (g)	2651.5	2525.8	3763.0	3605.1	2316.2
Vol Rinse #1 (mL)	200	200	200	200	200
Vol Rinse #2 (mL)	150	200	200	200	200
Vol Rinse #3 (mL)	0	100	200	200	150
Vol Rinse #X (mL)	0	0	150	150	150
Shake Time per Rinse (min)	5	5 *	10 *	10 *	10 *
Weight Erlenmeyer (g)	215.527	243.147	257.284	357.946	222.156
Erlenmeyer + Extract (g)	619.590	932.649	1125.810	1525.077	1096.738
Extract (g) calc.	404.063	689.502	868.526	1167.131	874.582
Vial 1 + label (g)	14.999	15.072	14.909	15.031	14.886
Vial 2 + label (g)	14.109	14.979	15.057	15.044	14.943
Vial 3 + label (g)	14.979	14.968	14.924	14.923	15.034
Vial 4 + label (g)	15.041	14.973	14.957	14.934	15.033
Vial 1 + lid (g)	16.511	16.579	16.446	16.551	16.410
Vial 2 + lid (g)	16.618	16.498	16.560	16.574	16.460
Vial 3 + lid (g)	16.516	16.492	16.386	16.430	16.572
Vial 4 + lid (g)	16.550	16.475	16.490	16.482	16.583
Vial 1 +lid +extract (g)	42.957	42.591	41.572	42.863	42.171
Vial 2 +lid +extract (g)	42.592	42.113	42.452	42.956	42.696
Vial 3 +lid +extract (g)	42.311	42.168	42.699	42.684	42.604
Vial 4 +lid +extract (g)	42.355	42.127	42.815	42.130	42.664
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 4)

TASK	Sample ID # CP2-8-1C	Sample ID # CP2-9-1A	Sample ID # CP2-9-1B	Sample ID # CP2-9-1C	Sample ID # CP2-10-1A
Processing Date:	17.08.96	18.08.96	18.08.96	18.08.96	11.08.96
Weight Oiled Sediment (g)	1585.1	4411.4	2393.5	677.8	3838.5
Container (g)	580.1	584.2	588.1	581.6	19.0
Cont.+Oiled Sediment (g)	2165.2	4995.6	2981.6	1259.4	3857.5
Vol Rinse #1 (mL)	200	200	200	150	200
Vol Rinse #2 (mL)	150	150	200	100	200
Vol Rinse #3 (mL)	100	150	150	0	150
Vol Rinse #X (mL)	0	150, 150	150**	0	0
Shake Time per Rinse (min)	10 *	10 *	10 *	10 *	5
Weight Erlenmeyer (g)	215.553	408.067	257.167	165.510	276.887
Erlenmeyer + Extract (g)	707.796	1540.997	1044.007	461.021	821.914
Extract (g) calc.	492.243	1132.930	786.840	295.511	545.027
Vial 1 + label (g)	15.031	14.936	14.840	15.027	15.062
Vial 2 + label (g)	14.950	15.076	14.938	14.898	15.108
Vial 3 + label (g)	14.825	15.156	15.077	15.031	15.139
Vial 4 + label (g)	14.968	15.003	15.122	14.872	15.084
Vial 1 + lid (g)	16.558	16.474	16.366	16.546	16.580
Vial 2 + lid (g)	16.466	16.658	16.445	16.473	16.655
Vial 3 + lid (g)	16.370	16.750	16.587	16.584	16.672
Vial 4 + lid (g)	16.475	16.544	16.665	16.445	16.640
Vial 1 +lid +extract (g)	42.773	41.888	41.587	43.002	42.456
Vial 2 +lid +extract (g)	42.480	42.491	41.665	42.447	42.658
Vial 3 +lid +extract (g)	42.071	42.841	41.944	42.773	42.352
Vial 4 +lid +extract (g)	42.628	42.539	42.155	42.633	42.083
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 5)

TASK	Sample ID # CP3-1-1A	Sample ID # CP3-1-1B	Sample ID # CP3-2-1A	Sample ID # CP3-3-1A	Sample ID # CP3-3-1B
Processing Date:	18.08.96	18.08.96	19.08.96	19.08.96	19.08.96
Weight Oiled Sediment (g)	3815.0	3845.2	3697.1	3411.2	4214.5
Container (g)	581.0	580.7	586.9	579.6	582.8
Cont.+Oiled Sediment (g)	4396.0	4425.9	4284.0	3990.8	4797.3
Vol Rinse #1 (mL)	200	200	200	200	200
Vol Rinse #2 (mL)	200	150	150	200	200
Vol Rinse #3 (mL)	100	100	100	200	200
Vol Rinse #X (mL)	0	0	0	150	150
Shake Time per Rinse (min)	10 *	10 *	10 *	10 *	10 *
Weight Erlenmeyer (g)	287.359	168.240	163.572	287.425	249.529
Erlenmeyer + Extract (g)	851.078	369.991	499.789	1166.470	1150.297
Extract (g) calc.	563.719	201.751	336.217	879.045	900.768
Vial 1 + label (g)	15.106	15.000	14.989	14.915	15.044
Vial 2 + label (g)	15.156	15.068	14.980	15.004	14.970
Vial 3 + label (g)	14.970	14.942	15.037	15.014	15.008
Vial 4 + label (g)	14.992	14.923	14.955	15.079	15.083
Vial 1 + lid (g)	16.665	16.534	16.523	16.592	16.468
Vial 2 + lid (g)	16.720	16.646	16.555	16.554	16.528
Vial 3 + lid (g)	16.529	16.498	16.598	16.551	16.564
Vial 4 + lid (g)	16.547	16.465	16.500	16.635	16.658
Vial 1 +lid +extract (g)	43.185	42.703	42.560	41.797	42.298
Vial 2 +lid +extract (g)	43.015	42.851	42.706	42.430	42.341
Vial 3 +lid +extract (g)	42.279	42.823	42.595	42.771	42.288
Vial 4 +lid +extract (g)	42.964	42.422	42.487	42.742	42.742
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 6)

TASK	Sample ID # CP3-4-1A	Sample ID # CP3-5-1A	Sample ID # CP3-5-1B	Sample ID # CP3-6-1A	Sample ID # CP3-7-1A
Processing Date:	19.08.96	19.08.96	19.08.96	19.08.96	19.08.96
Weight Oiled Sediment (g)	4293.6	3442.3	4465.3	3341.4	2961.8
Container (g)	581.8	586.4	582.3	587.1	580.4
Cont.+Oiled Sediment (g)	4875.4	4028.7	5047.6	3928.5	3542.2
Vol Rinse #1 (mL)	200	200	200	200	200
Vol Rinse #2 (mL)	150	150	100	150	100
Vol Rinse #3 (mL)	0	0	0	0	0
Vol Rinse #X (mL)	0	0	0	0	0
Shake Time per Rinse (min)	10 *	10 *	10 *	10 *	10 *
Weight Erlenmeyer (g)	168.249	163.632	168.503	163.728	165.471
Erlenmeyer + Extract (g)	480.429	535.381	365.037	425.933	477.539
Extract (g) calc.	312.180	371.749	196.534	262.205	312.068
Vial 1 + label (g)	14.893	14.969	14.832	15.045	14.997
Vial 2 + label (g)	14.916	15.009	14.999	14.924	15.040
Vial 3 + label (g)	14.974	15.002	14.963	15.028	15.133
Vial 4 + label (g)	15.104	14.931	14.946	15.163	14.991
Vial 1 + lid (g)	16.436	16.505	16.395	16.578	16.566
Vial 2 + lid (g)	16.481	16.587	16.549	16.463	16.619
Vial 3 + lid (g)	16.543	16.587	16.494	16.587	16.704
Vial 4 + lid (g)	16.632	16.492	16.497	16.720	16.536
Vial 1 +lid +extract (g)	42.972	42.476	42.633	43.042	43.023
Vial 2 +lid +extract (g)	42.737	42.571	43.038	42.328	42.751
Vial 3 +lid +extract (g)	42.649	42.624	43.069	43.109	43.259
Vial 4 +lid +extract (g)	42.907	42.514	42.685	43.255	42.844
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

APPENDIX I. Laboratory Log of Sediment Extractions (Page 7)

TASK	Sample ID # CP3-7-1B	Sample ID # CP3-8-1A	Sample ID # CP3-9-1A	Sample ID # CP3-9-1B	Sample ID # CP3-10-1A
Processing Date:	19.08.96	20.08.96	20.08.96	20.08.96	20.08.96
Weight Oiled Sediment (g)	3794.4	3703.9	3644.6	3641.6	3629.0
Container (g)	583.1	581.1	585.5	579.2	584.3
Cont.+Oiled Sediment (g)	4377.5	4285.0	4230.1	4220.8	4213.3
Vol Rinse #1 (mL)	200	175	200	200	200
Vol Rinse #2 (mL)	150	200	200	200	200
Vol Rinse #3 (mL)	0	100	200	200	100
Vol Rinse #X (mL)	0	0	100	100	0
Shake Time per Rinse (min)	10 *	5	5	5	5
Weight Erlenmeyer (g)	162.237	168.345	365.532	381.508	165.447
Erlenmeyer + Extract (g)	476.882	677.871	1325.261	1406.485	679.518
Extract (g) calc.	314.645	509.526	959.729	1024.977	514.071
Vial 1 + label (g)	15.122	14.964	14.964	14.927	14.983
Vial 2 + label (g)	14.931	14.928	15.090	15.004	15.056
Vial 3 + label (g)	14.937	15.004	14.844	15.058	14.947
Vial 4 + label (g)	15.155	15.009	14.978	15.038	14.912
Vial 1 + lid (g)	16.661	16.531	16.488	16.446	16.523
Vial 2 + lid (g)	16.483	16.477	16.612	16.534	16.599
Vial 3 + lid (g)	16.534	16.564	16.419	16.606	16.477
Vial 4 + lid (g)	16.689	16.589	16.545	16.579	16.543
Vial 1 +lid +extract (g)	43.197	43.373	42.617	41.879	43.075
Vial 2 +lid +extract (g)	42.273	43.062	43.075	42.364	42.856
Vial 3 +lid +extract (g)	42.848	43.157	42.091	42.581	42.657
Vial 4 +lid +extract (g)	43.333	43.490	42.629	42.255	42.892
Weight Beaker (g)	nm	nm	nm	nm	nm
Weight Beaker + water (g)	nm	nm	nm	nm	nm
Weight water (g) calc.	nm	nm	nm	nm	nm

Appendix II. Gravimetrically-determined TSEM and GC-determined TPH for Svalbard Samples

Extraction Date	Sample Code	Weight of 10 ml Extract (g)	TSEM of 10 ml extract (g)	% TSEM in extract	Conc. of Extract (mgTSEM / g ext)	Weight of Sediments (g)	Total Weight of Extract (g)	Total Weight of TSEM (mg)	Conc.of TSEM (mg TSEM/g sed)	GC-TPH (mg/g TSEM)	GC-TPH (mg/g sed)
Aug. 16	CP1-5-1A	12.5098	1.8394	14.70	147.04	4888.8	910.727	133910	27.39	666	18.24
Aug. 11	CP2-1-1A	13.0151	0.7152	5.50	54.95	5027.9	743.288	40844	8.12	634	5.15
Aug. 16	CP2-1-1B	13.3852	0.4535	3.40	33.88	2030.2	1052.990	35675	17.57	632	11.11
Aug. 16	CP2-1-1C	13.6703	0.0343	0.25	2.51	1359.8	404.983	1016	0.75	680	0.51
Aug. 16	CP2-2-1A	12.8537	0.7051	5.50	54.86	3505.0	585.004	32093	9.16	705	6.46
Aug. 16	CP2-3-1A	12.7798	0.3860	3.00	30.20	3096.1	874.976	26424	8.53	664	5.67
Aug. 16	CP2-4-1A	12.7625	0.9747	7.60	76.37	2831.7	810.036	61862	21.85	666	14.55
Aug. 16	CP2-4-1B	13.1434	0.5900	4.49	44.89	2143.7	1032.980	46370	21.63	694	15.01
Aug. 16	CP2-4-1C	13.1620	0.0097	1.00	9.57	2841.7	351.265	3362	1.18	677	0.80
Aug. 16	CP2-5-1A	12.9110	0.6163	4.80	47.73	3208.8	980.222	46786	14.58	665	9.70
Aug. 16	CP2-5-1B	12.3536	0.041	0.30	3.32	2632.7	404.063	1341	0.51	686	0.35
Aug. 16	CP2-6-1A	12.7287	0.2378	1.90	18.68	1943.9	689.502	12880	6.63	696	4.61
Aug. 17	CP2-7-1A	13.2639	0.7428	5.60	56.00	3178.5	868.526	48639	15.30	686	10.50
Aug. 17	CP2-8-1A	13.3768	0.3161	2.36	23.63	3021.7	1167.131	27580	9.13	679	6.20
Aug. 17	CP2-8-1B	13.0126	0.4115	3.16	31.62	1735.8	874.582	27657	15.93	679	10.82
Aug. 17	CP2-8-1C	13.4271	0.0336	0.25	2.50	1585.1	492.243	1232	0.78	684	0.53
Aug. 18	CP2-9-1A	13.1541	0.7708	5.86	58.60	4411.4	1132.930	66387	15.05	686	10.32
Aug. 18	CP2-9-1B	13.1148	0.5672	4.32	43.25	2393.5	786.840	34030	14.22	682	9.70
Aug. 18	CP2-9-1C	13.3983	0.0103	0.08	0.77	677.8	295.511	227	0.34	567	0.19
Aug. 18	CP2-10-1	13.2047	0.2163	1.60	16.38	3838.5	545.027	8928	2.33	696	1.62

Appendix II. Gravimetrically-determined TSEM and GC-determined TPH for Svalbard Samples

Extraction Date	Sample Code	Weight of 10 ml Extract (g)	TSEM of 10 ml extract (g)	% TSEM in extract	Conc. of Extract (mgTSEM / g ext)	Weight of Sediments (g)	Total Weight of Extract (g)	Total Weight of TSEM (mg)	Conc.of TSEM (mg TSEM/g sed)	GC-TPH (mg/g TSEM)	GC-TPH (mg/g sed)
Aug. 18	CP3-1-1A	13.3735	0.0844	0.63	6.31	3815.0	563.719	3558	0.93	652	0.61
Aug. 18	CP3-1-1B	13.3299	0.0647	0.49	4.85	3845.2	201.751	979	0.25	674	0.17
Aug. 19	CP3-2-1A	13.1377	0.0710	0.54	5.40	3697.1	336.217	1817	0.49	690	0.34
Aug. 19	CP3-3-1A	13.0281	0.3159	2.42	24.25	3411.2	879.045	21315	6.25	619	3.87
Aug. 19	CP3-3-1B	12.9128	0.5424	4.20	42.00	4214.5	900.768	37837	8.98	652	5.85
Aug. 19	CP3-4-1A	13.2436	0.0429	0.32	3.24	4293.6	312.180	1011	0.24	684	0.16
Aug. 19	CP3-5-1A	13.6970	0.0302	0.22	2.20	3442.3	371.749	820	0.24	691	0.16
Aug. 19	CP3-5-1B	13.1014	0.0102	0.08	0.78	4465.3	196.534	153	0.034	674	0.023
Aug. 19	CP3-6-1A	13.7402	0.0270	0.20	1.97	3341.4	262.205	515	0.15	610	0.09
Aug. 19	CP3-7-1A	13.2567	0.0092	0.07	0.69	2961.8	312.068	217	0.073	622	0.045
Aug. 19	CP3-7-1B	13.3624	0.0042	0.03	0.31	3794.4	314.645	99	0.026	720	0.019
Aug. 20	CP3-8-1A	13.1576	0.0346	0.26	2.63	3703.9	509.526	1340	0.36	623	0.23
Aug. 20	CP3-9-1A	12.9951	0.5334	4.10	41.05	3644.6	959.729	39393	10.81	623	6.73
Aug. 20	CP3-9-1B	12.4080	0.7298	5.88	58.82	3641.6	1024.977	60286	16.55	660	10.93
Aug. 20	CP3-10-1	12.6854	0.0518	0.41	4.08	3629.0	514.071	2099	0.58	649	0.38

APPENDIX III. Plots of Grain Size Analysis Composited for All Sites by Intertidal Zonation and the Control Plot by Sample.